ENGINEERING NOW

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Clustering technologies stimulates innovation

It's Microsoft's Cloud, but the company credits Virginia Tech with using the data collector to accelerate the discovery and mapping of genes

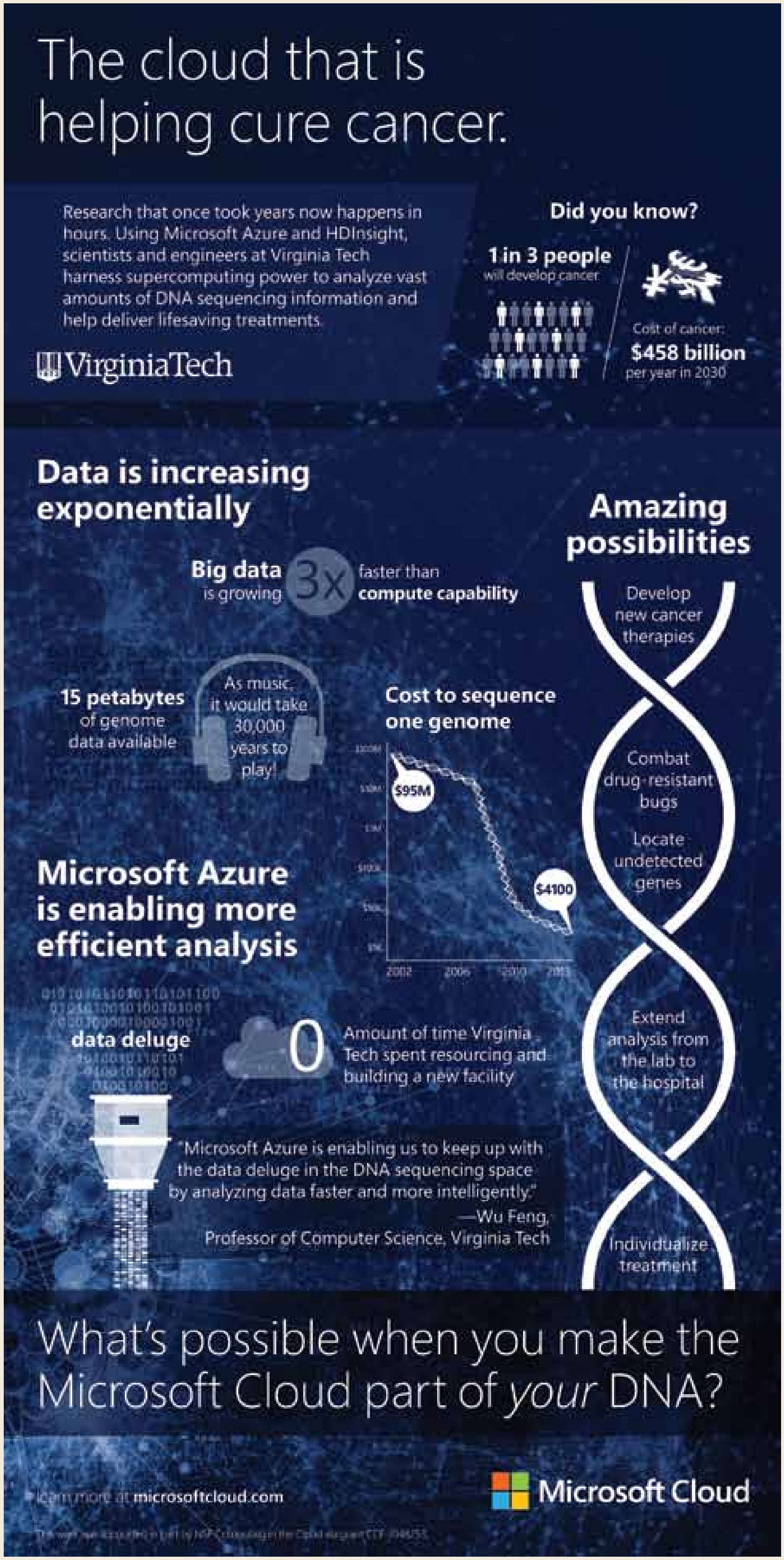
Virginia Tech's College of Engineering is exemplary in its leadership in interdisciplinary doctoral studies, with many of its graduate school candidates supported by the Institute for Critical Technology and Applied Science (ICTAS). A number of these students are featured in this publication.

The advertisement replicated below (with permission from Microsoft) exemplifies one industry's acknowledgement of our premier interdisciplinary research.

Microsoft, the multinational corporation headquartered in Redmond, Washington, selected our university, Virginia Tech, as a focal point to include in its advertising campaign in 2014. More importantly, Microsoft focused on the work spearheaded by Wu Feng, a professor in the departments of computer science and electrical and computer engineering as well the founder of an ICTAS laboratory, Synergistic Environments for Experimental Computing (SEEC). In the past few years, Feng has leveraged a National Science Foundation (NSF) grant on big data with an earlier $6 million award from the Air Force, and an NSF agreement with Microsoft on a collaborative cloud computing agreement. As he wove together the results from each grant, he was able to tell a much larger, more interconnected story — in doing so, he was looking at furthering the promise of personalized and customized medicine.

Microsoft focused on Feng's leadership in this cutting-edge research, succinctly working the collaborative ideas into the ad saying, Virginia Tech scientists and engineers are leaders in harnessing supercomputer powers to deliver lifesaving treatments.

This full-page ad ran in May, June, and July of 2014 in the *Washington Post, New York Times, USA Today, Wall Street Journal, Bloomberg Businessweek, United Hemispheres, The Economist, Forbes, Fortune, TIME, Popular Mechanics*, and *Golf Digest*, as well as a host of other venues in Philadelphia, Washington, D.C., and Baltimore. To the right is the infographic on Feng's research, also developed by Microsoft. The Microsoft ad validates the achievements of the College of Engineering's interdisciplinary nature of its research graduate program.



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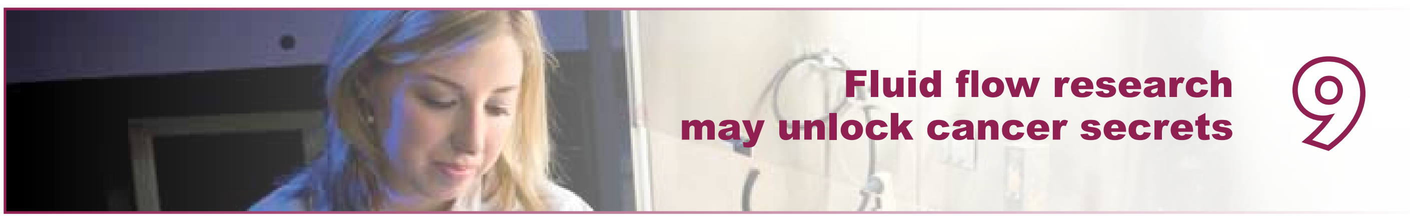

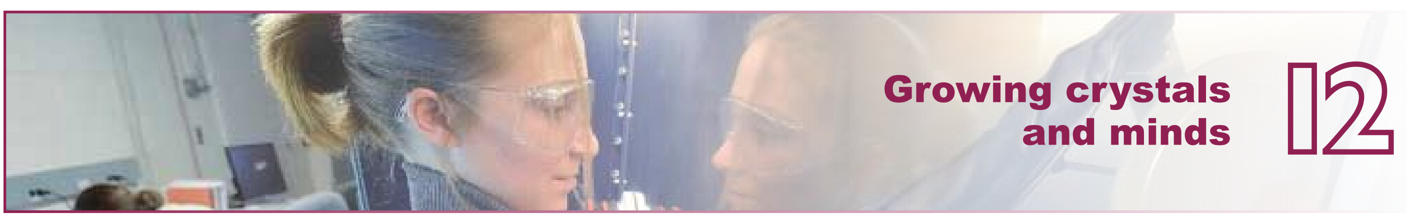

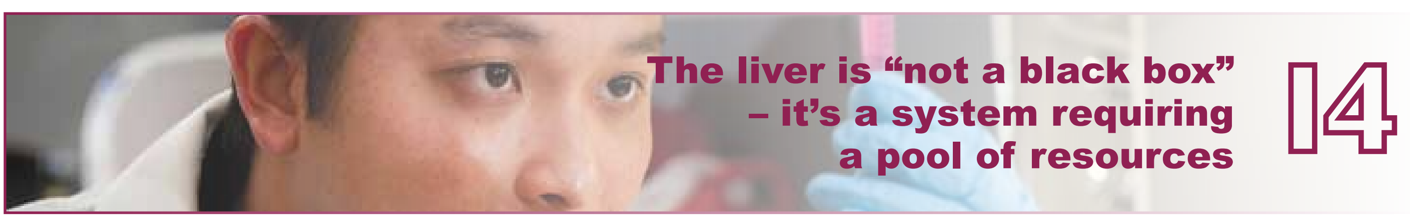

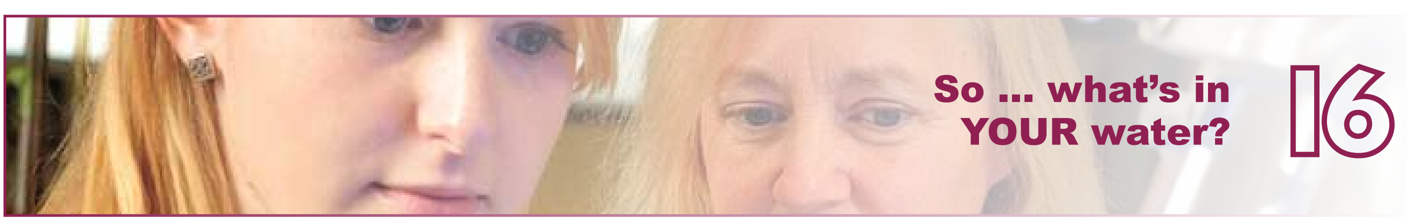

ON THE COVER

Jim Stroup combined several shots to illustrate the work of Yuan Lin who is creatively looking at the Federal Aviation Administration's air traffic control system and seeking to improve its efficiency by mimicking nature.

Dean's Message

Clustering critical technologies attracts best doctoral candidates

An ambitious plan was set in motion in 1997 by forward-thinking leaders of the Virginia Tech College of Engineering to create an academic atmosphere that would be more entrepreneurial in nature, and one that would focus on collaborative research.

As the plan developed, college leaders traveled to peer institutions where they could learn from such programs already in the pipeline, including the Georgia Tech Research Institute and the Beckman Institute for Advanced Science and Technology at the University of Illinois. In the case of the latter, our emissaries learned that a $40 million gift and a $10 million capital appropriation from the state of Illinois created the Beckman Institute (http://www.beckman.uiuc.edu/) some 12 years prior to their visit. At that time, Illinois provided an annual budget of $3.5 million for infrastructure maintenance and core support staff. Commencing operations in 1989, the annual research expenditure had reached $9 million by 1993. By fiscal year 2000 when Virginia Tech visited the institute, its research expenditures had reached $106 million.

The Virginia Tech leaders, including then Dean William F. Stephenson and Associate Dean Malcolm McPherson, took note. They understood that an initial investment allowed an enterprise to reach critical mass. They saw that a progressive and collaborative research structure could accomplish much over a ten-year period. Decisively, they moved forward.

Today, Virginia Tech's Institute for Critical Technology and Applied Science (ICTAS), led by the College of Engineering, is closing in on its own ten-year milestone. And in doing so, ICTAS has found reason to celebrate. Virginia Tech's ICTAS, led by Roop Mahajan who holds the Lewis A. Hester Chair in Engineering, has now surpassed some of the older institutes the founders used to benchmark their efforts. In fact Virginia Tech's ICTAS is now among the elite and one of the institutes to emulate.

The number of faculty supported through ICTAS affiliations has tripled from some 100 in 2006 to 306 in 2013. Research expenditures have escalated from $10 million in 2006 to $103 million in 2013.

And these numbers in turn reflect the ability of ICTAS to support graduate students through seed awards and through its doctoral scholars program. In 2006, 42 students were aided by the ICTAS umbrella; in 2013, that number was 189 – a more than four-fold increase.

This issue of *Engineering Now* focuses on some of the doctoral students who have gained partial or full support from ICTAS. Their work reflects the synergy found by clustering research groups, bringing together teams of engineers and scientists and medical faculty.

As an example, biomedical engineer Brittany Balhouse, a Ph.D. candidate, works in a lab that partners with Wake Forest University, the Virginia Tech-Maryland Regional College of Veterinary Medicine, and the Edward Via College of Osteopathic Medicine.

Another student, Mark Palframan, is an aerospace engineering doctoral student who spends many of his days at Virginia Tech's Kentland Research Farm, one of six federally certified drone test sites named by the Federal Aviation Administration. Palframan was a critical part of an earlier investigation about microbes in the atmosphere and their effect on agricultural crops and plant life. He developed a system to capture particulates and inject them into a specific biosensor that was part of an unmanned aircraft system. His recent work tests prototype wings and other aerospace applications.

We hope you will read this issue of *Engineering Now*, and learn more about how we have pulled together thematic concentrations that reflect the needs of the Commonwealth and the nation. These areas are growth oriented, and seen to have the highest potential for further development, education, and economic impact. And we are pleased to be able to offer these real-world interdisciplinary projects to our next generation of problem solvers.

Richard C. Benson

Richard Benson,
Dean, College of Engineering
Paul and Dorothea Torgersen Chair of Engineering

Richard Benson, dean of Virginia Tech's College of Engineering, led the efforts to make the Signature Engineering Building a living laboratory that will foster collaborative research and hands-on, minds-on learning.

Nature inspires creative minds

By Lindsey Haugh

Air travelers in today's environment often experience delays as a result of numerous airplanes on the ground and in the air at any given moment.

According to the Federal Aviation Administration (FAA), extensive planning is underway to make the best use of new and existing technology, infrastructure, and employees to handle the doubling and tripling of air traffic expected in the coming decades. Satellite-based navigation will allow aircraft to fly more direct routes and navigate around inclement weather, increase airspace capacity, and reduce delays.

Yuan Lin, an engineering science and mechanics master's and doctoral student in the College of Engineering at Virginia Tech, is working to develop a novel air traffic control algorithm inspired by nature. He is confident his research on bat swarming behaviors can effectively impact the current predicament of our air traffic control system.

Born in Guangdong, China, Lin initially pursued medicine during his undergraduate studies while at Nanchang University, China. Lin changed directions after he realized he lacked passion for his current track of study. Architecture – or rather the way buildings were masterfully constructed – always fascinated him, and so he opted to pursue his bachelor's in civil engineering.

After nine months at Virginia Tech, Lin met Nicole Abaid, assistant professor of engineering science and mechanics, who introduced him to dynamical systems and control. He became fascinated by the theoretical application of creating robotic

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Photo by Jim Stroup

Karl Bitikofer holds an ultrasonic sensor. He worked with the researchers to develop the first generation agent-based model of the bat swarm.

Faculty member Nicole Abaid and Ph.D. scholar Yuan Lin work on models for bat swarms using acoustic sensing that engages them in engineering and in biology studies.

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vehicles to avoid collisions – the same way bats maneuver. Shortly after their meeting, Lin joined Abaid's research group and currently works on a joint project with Rolf Müller, associate professor of mechanical engineering, funded by the Institute for Critical Technology and Applied Science at Virginia Tech.

Through observation of different animal species, the team found when bats fly they don't have difficulty flying near many peers. A large number of bats can simultaneously fly out of a cave without collisions with each other at night in the dark. Instead of using vision, they use echolocation. They emit pulses and process received echoes to locate targets in the environment. They switch frequencies, differentiating their own from their peers, to avoid frequency jamming.

"We developed the first generation agent-based model of the bat swarm, modeling it directly after the bats emerge from the caves through echolocation," said Lin.

"It's been rewarding for me to work with Yuan on models for bat swarms using acoustic sensing because we get to constantly go back and forth between engineering and biology, balancing tractable math with complex phenomena observed by biologists," said Abaid. "I feel lucky that Yuan, although he's an engineer, is interested in straddling these two worlds, as it lets us get exciting and possibly more relevant results."

Lin is enthusiastic about the addition of Pat Artis, an ESM alumnus and professor of practice, to his doctoral defense committee. "Since he is a pilot and has worked directly in the industry, he had practical knowledge from experience that will be extremely helpful to my research," Lin said of the Fortune 500 consultant and expert on aviation control systems.

Through collaboration and detailed research, Lin hopes to propose an innovative and applicable control algorithm for air traffic, so future airport delays may be limited and air travelers might have more pleasing experiences.

Inspired by the late Steve Jobs, Lin is convinced his role and commitment to solving air traffic quandaries and environmental dilemmas, "as a true scientist, is to make life simple, easier, and more beautiful."

"It's been rewarding for me to work with Yuan on models for bat swarms using acoustic sensing because we get to constantly go back and forth between engineering and biology ..."

~ Nicole Abaid

Photo by Jim Stroup

Photo by Jim Stroup

Mark Palframan, center, works on and is primary pilot of the E-SPAARO unmanned plane, part of the Virginia Tech's Nonlinear Systems Lab. Flanking him are John Coggin (at left), a senior research associate at Virginia Tech's Institute for Critical Technology and Applied Science, and (at right) fellow engineering doctoral student Chris Kevorkian.

Aerospace student pilots unmanned planes with an eye toward uses that vary from agriculture to disaster responses

by Steven Mackay

When Mark Palframan sets to work, he's at Virginia Tech's Kentland Research Farm. No dirt is involved, though. His hands are on a souped-up remote control device, and his eyes look to the air, set sharp on the unmanned E-SPAARO aircraft as it soars 400 hundred feet above the ground.

The Electric-SPAARO – short for Small Platform for Autonomous Aerial Research Operations –is a small unmanned aerial system operated by Virginia Tech's Nonlinear Systems Lab that can fly either autonomously or by remote control. It is used for testing prototype wings and control surfaces, validating air-data sensors, and collecting and analyzing air samples. This is not a toy of play. Its mission, and that of the lab's, is forward-looking research.

A doctoral student originally from Middletown, N.J., Palframan arrived at Virginia Tech as a master's student having no prior experience with aircraft. As an undergraduate at Pennsylvania's Lafayette College, he studied mechanical engineering with a focus on turbulent flow structures in water. There, Palframan built a highly precise water channel to carry out vortex visualization experiments.

"Being able to do cutting-edge, hands-on research was exciting, and it was at that point that I knew I wanted to do more," he said. More, though, meant change. Palframan decided to refocus his studies on control theory. After seeing the Nonlinear Systems Lab, where students could validate research on their own aerial autonomous systems that they also designed, built and tested, Palframan found he was hooked.

Palframan's role at the lab, run by Craig Woolsey and Mazen Farhood of the department of aerospace and ocean engineering, started with support roles on the flying team and taking a class to prep for the Federal Aviation Administration private pilot exam. He trained on a small, remote-controlled T-28 Trojan trainer plane. When the lab's designated pilot left, Palframan moved into the role, serving as E-SPAARO's main pilot. He also worked on building, maintaining, and regulating the lab's unmanned aircraft fleet.

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Members of the Virginia Tech Nonlinear Systems Laboratory use Kentland Farm as a base to fly their autonomous aircraft, including airplanes and helicopters.

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"The E-SPAARO platform is essentially a flying pick-up truck, albeit a pretty one," Palframan said.

The vehicle is tasked with carrying a large payload, so its design is modular with changeable wings and fuselage panels. It can carry a wide array of sensors and computer boards for handling different in-flight experiments. The removable wing design allows experimental, flexible wings to be easily tested, with sensors and cameras tracking shape changes in the wing as it flies. In addition to research at Virginia Tech, Palframan has worked with several commercial groups, including NASK Inc., Blackbird Technologies Inc., and Aeroprobe Corp., the latter based in the Virginia Tech Corporate Research Center.

Palframan worked on his master's thesis under Woolsey and David Schmale III, an associate professor with the College of Agriculture and Life Sciences, who studies microbes in the atmosphere and their effect on crops and plant life.

"Mark developed a system to capture particulates from the atmosphere and inject them into a miniaturized Surface Plasmon Resonance biosensor that he integrated into our SPAARO unmanned aircraft system," said Woolsey. "This device can provide a precise measurement of the concentration of a specific biological agent – for example, anthrax – in a sample. As far as we know, this was the first time an SPR device had been flown and operated aboard an autonomous aircraft."

Palframan is now using E-SPAARO for his dissertation, which focuses on designing, testing, and analyzing autopilot programs for autonomous aircraft. It is hoped the programs would allow the aircraft to precisely follow a prescribed flight path while handling external disturbances, such as wind and turbulence, sensor noise, and uncertainty in the mathematical model of the aircraft.

"The idea is to cut out expensive ground testing, such as in a wind tunnel, which would be aimed at generating a highly accurate mathematical model of the aircraft to use in the generation of an autopilot controller," Palframan said. "Instead, we take a potentially less accurate mathematical model, which is much easier to obtain, and incorporated uncertainty analysis into the controller design process to create a controller that's guaranteed to be successful in the midst of disturbances and uncertainties."

Palframan said he wishes to continue working with unmanned aircraft. After gaining industry experience, he sees himself re-entering academia as a professor. The education bug hit Palframan when he was teaching sophomore-level aerospace labs.

"It can be very rewarding to see the things you're teaching finally click with the students," he said.

Mark Palframan, a member of the Virginia Tech Nonlinear Systems Laboratory, pilots the E-SPAARO craft. It operates by both remote control and autonomously.

studies span veterinary school, medical schools, and biomedical engineering

fluid flow research may unlock cancer secrets

by Lynn Nystrom

Sometimes, good health might be all about the fluids.

In the human body, the channels that fluids take as they migrate through tissues can impact a person's health. Abnormal fluid flow can help account for the development or progression of diseases, such as cancer.

By incorporating these fluid forces into tumor models in a laboratory, cancer cell responses to those forces and to anti-cancer drugs better represent the responses by cells in the body. The knowledge gained from studying these responses is advancing the growing field of personalized medicine that allows each person to be treated somewhat differently.

Researchers worldwide are investigating these physiological responses.

One is Brittany Balhouse, a doctoral candidate at Virginia Tech, who has worked with Marissa Nichole Rylander, formerly of the Virginia Tech-Wake Forest University School of Biomedical Engineering and Sciences (SBES) and now with Scott Verbridge, assistant professor of the SBES and director of the Laboratory for Integrative Tumor Ecology (LITE). Rylander is a National Science Foundation CAREER Award recipient for her notable achievements in this area. Verbridge's expertise is in cancer biology, tissue engineering, and nanobiotechnology.

Balhouse is using Rylander's work as a foundation for her current research in the Tissue Engineering, Nanotechnology, and Cancer Research (TENCR) Laboratory in SBES. She is also continuing some of the work of one of Rylander's previous graduate students, Cara Buchanan.

Buchanan, after earning her Ph.D., now works in Switzerland at the Laboratory of Lymphatic and Cancer Bioengineering at the Ecole Polytechnique Federale of Lausanne under the supervision of Melody Swartz.

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A syringe is used to place the tissue mimic into a tubing that lends support and optical access. A microfluidic channel can then be created in the center of the tissue mimic, modeling a tumor blood vessel.

Photo by Logan Wallace

By modeling tumor blood vessels, Brittany Balhouse is then able to see how the cells in the tissue react to different mechanical stimuli or cancer therapies.

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Balhouse chose to study at Virginia Tech's School of Biomedical Engineering and Sciences (SBES) because of its strong partnerships between clinicians, scientists, and engineers. SBES is a joint entity with Wake Forest University, housing one of the top 50 medical schools in the country. Also, the Virginia Tech-Maryland Regional College of Veterinary Medicine and the Edward Via College of Osteopathic Medicine in Blacksburg, Va., cooperate extensively with ongoing research at SBES.

When Balhouse started as a SBES graduate student she had the opportunity to be paired with oncologists at Wake Forest Baptist Medical Center, and witnessed some of the latest techniques in surgery and radiation therapy. Additionally, her introduction included several days shadowing clinicians at the Veterinary Medicine College and the osteopathic school of medicine.

Hence, she reinforced her thinking that if she studied and pursued a career in biomedical engineering as opposed to becoming a physician she could "affect millions of people, rather than thousands, by performing excellent research and inspiring others to do the same," Balhouse said.

How can she affect millions? Her study aims to discover potential causes of cancer progression by modeling the tumor, the forces therein, and its progression in the lab.

"We are determining which environmental stresses trigger metastasis. For instance, how fluid forces in the tumor could trigger cancer cells to leave the primary site and form secondary tumors elsewhere in the body, " she said. The model will also be used for testing current and novel anti-cancer drugs.

The standard way to test anti-cancer drugs before clinical trials is with cancer cells in a Petri dish. However, the Petri dish bears little resemblance to the microenvironment, the mechanical and chemical signals, to which cancer cells are exposed in the tumor. Consequently, one of Balhouse's major efforts is to engineer the tumor microenvironment, mimicking conditions in the body to better understand the process of tumor growth and features of the environment that lead to progression; the efficacy of new treatments can be tested using these engineered tumor systems. Her model incorporates many of the environmental components that are present in the body so the cells will respond to drugs in a realistic manner ultimately leading to success during clinical trials.

"Our model is unique in its physiological geometry, cellular and material composition, and capability to characterize the tumor response to blood flow as compared to other tumor models currently in use," Balhouse explained.

Other students working with Balhouse in the TENCR Lab are developing nanotechnologies that will selectively kill cancer cells, leaving normal cells unharmed. Their system will eventually be tested in Balhouse's model and she will compare its effectiveness compared to current chemotherapeutics.

"Imagine all the time, money, and, most importantly, lives that could be saved by simply testing novel therapies in a more physiologically representative model first," Balhouse added.

Brittany Balhouse has an Institute for Critical Technology and Applied Science Doctoral Scholarship, honoring her exceptional academic credentials. The award comes with full tuition, a graduate student stipend, partial travel support, and experience in interdisciplinary research.

Photo by Logan Wallace

Growth medium is supplied to breast cancer cells, helping the cells to grow.

Working with electrical and materials science engineers, Rachel Umbel monitors the crystal growing in a 1000-degree Celsius environment.

Growing crystals and minds

By Lindsey Haugh

Semiconductors are one of the nation's top exports and are a strategically important industry for the economy and national security. In 2012, the Semiconductor Industry Association (SIA) reported semiconductors were primarily responsible for the global trillion-dollar electronics industry. In the U.S. alone, semiconductor companies generated $146 billion in sales.

The fabrication of semiconductor materials is essential to the field of power electronics and necessary for the following applications: energy efficiency, energy storage, energy distribution, communication, and computer systems.

Rachel Umbel, a doctoral student in the materials science and engineering program at Virginia Tech, is working with gallium nitride to grow crystals. The chemical compound has properties superior to silicon, the dominant platform in building semiconductors and ultimately, power electronics.

Prior to her research in Blacksburg, Umbel obtained her bachelor's degree in physics and was enrolled in the honors college at the Indiana University of Pennsylvania. On an internship in 2010, Umbel had the opportunity to study under Nobel laureate, Eric Cornell at the University of Colorado-Boulder. During another National Science Foundation-sponsored program, she collaborated with an international panel of researchers in the quest for gravitational waves at the University of Glasgow, Scotland.

Umbel works with a group of students advised by Lou Guido, an associate professor jointly appointed in both materials science and engineering and electrical and computer engineering. Guido's research group is made up of nine electrical engineering and materials science and engineering master and doctoral students.

"The combination of different educational backgrounds is perfect for interdisciplinary research," said Umbel, the lone female on the team. "What can be learned, not only in the lab, but over coffee and discussing our findings, is pretty exciting."

Together, they "bake out" the MOCVD reactor chamber using what Umbel compares to a self-cleaning oven. The slow process takes approximately two and a half hours in order to prevent flaking of the growing crystals. The second phase is the growth phase. Using a two-inch diameter wafer, the crystals grow at an incredibly

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hot temperature – 1,000 degrees Celsius. The crystal films are a couple microns thick -- thinner than a human hair.

The group constantly monitors the system, taking every safety precaution, because it uses toxic gases such as arsine. The gases are passed over a substrate and then break down, decomposing, creating the crystal. The system is maintained through a scrubber system, cleaning the exhaust gases before they are released, ridding it of toxic gases.

From beginning to end, the total growth time of a crystal is four hours.

Growing gallium nitride on silicon, otherwise known as crystals, will enable the manufacturing of integrated circuits and therefore, lower the cost of semiconductor device fabrication and further enhance the field of power electronics.

The young doctoral student is hopeful about the research and inspired to stay in the field after completing the doctoral program in 2015.

"And maybe after I defend, I will obtain an industry job with one of the world's largest semiconductor chip makers…like Intel," said Umbel with a grin. "Or maybe a travel adventure abroad before settling into my first real job."

Photo by Jim Stroup

Rachel Umbel examines the growing gallium nitride on silicon, otherwise known as crystals.

The liver is "not a black box" – it's a system requiring a pool of resources

by Steven Mackay

At the Institute for Critical Technology and Applied Science's Center for Systems Biology of Engineered Tissues, associate professor Padma Rajagopalan is leading a group of graduate and doctoral students in an effort to create a synthetic liver that one day could be a live saver for scores of people.

The effort, though, will be a long one, and is already more than a decade in the making. Medical experts well know the function of the liver. It plays an essential role in digestion and storing nutrients and the like essential for the body. But how does the liver work? How do the organ's cells do what they do, communicate with one another, and interact? Before any model is created, these puzzles – the liver's inner workings – must be solved.

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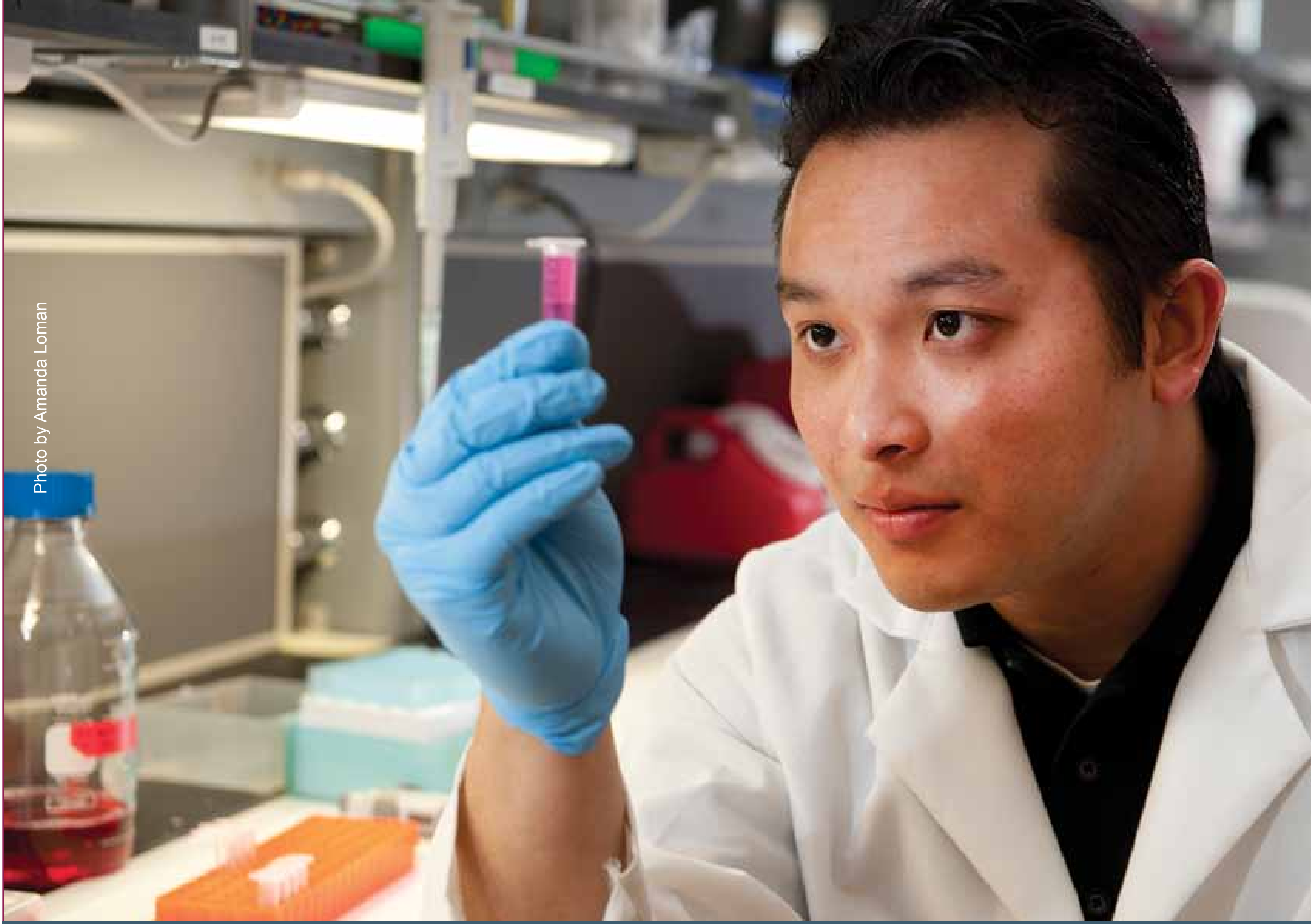
Lucas Vu, a doctoral student with the Institute for Critical Technology and Applied Science's Center for Systems Biology of Engineered Tissues, has a role in a long-term project to develop a synthetic liver.

Photo by Amanda Loman



Lucas Vu is tasked with studying nurturing testing, and watching liver cells is a part of his doctoral work.

That's where Lucas Vu comes in.

One of several Department of Chemical Engineering doctoral students working with Rajagopalan and the Virginia Tech – Wake Forest Department of Biomedical Engineering and Sciences, Vu focuses his work on studying, nurturing, testing, watching, and – yes, at times – killing a group of cells taken from healthy liver samples in rats and figuring out what makes them tick.

Three of the liver's four main cells types are part of Vu's daily focus, all stored in lab plates that fit on a human hand. He feeds them daily.

"The liver isn't a black box," said Vu, who works out of a high-tech lab in Kelly Hall, home of the Institute for Critical Technology and Applied Science. "People understand its function, but not how it functions, how it works. It is not well understood how the different cells interact or signal each other."

Just like building a successful national defense requires the correct understanding and training of soldiers and support personnel, scientists eager to build synthetic tissues – be it the liver, or heart valves, or even bone tissue – must understand how the various cells interact and combine efforts to carry out organ functions. Millions of cells are in any given sample, sending off millions of more electrical impulses and signals to one another, making the task infinitely challengeable.

Reactions by the cells as individuals and in type groups are carefully studied as Vu and his team add sugars, proteins, and vitamins – essential for a liver to function properly -- to test wells in the plates.

"Our research group is focusing on designing 3-D multi-cellular liver models to unearth the complex signaling pathways between liver cells," said Rajagopalan. "Lucas' research will provide information on how macrophages can affect liver function."

From Chandler, Arizona, Vu said his interest in chemistry started in high school. He can't quite put his finger on the why or how, but it was "the class I paid attention to more than others." With several engineers in the family – including his father – Vu took on chemical engineering as a major and then focus of study at Arizona State University.

His choice of Virginia Tech for earning a doctoral degree and continuing in his studies of the biomedical side of chemical engineering – he studied cancer cells as part of his master's work at Arizona State University – was multi-fold: He wanted the "college town experience," but "I really liked the department. They made me feel welcome." He started in 2011, focusing on teaching assistance duties and classes for undergraduate students. His move into the lab hooked him on the burgeoning field of biomedical engineering.

So … what's in YOUR water?

By Lynn Nystrom

Would you like your glass of water with a little iron it? Or do you prefer a copper taste? Possibly manganese? Did you realize that there are more than two dozen flavors to water, not all of which are as yummy as say, rocky road ice cream?

For several decades Andrea Dietrich, who trains utility staff and managers around the U.S. and across the globe on how to use sensory analysis to detect changes in water quality, has worked in the area of assessing taste, odor, and visual perception of chemical elements in water. Dietrich, a professor of civil and environmental engineering at Virginia Tech, has received numerous grants in this area, including one from the National Science Foundation. This $1.6 million contract asked her to investigate connections between corrosion of home plumbing materials, tastes-and-odors in drinking water, economics, and consumer health concerns.

For her research efforts, Dietrich has registered a number of firsts with journal papers reflecting her work on such diverse topics as: improving cancer therapy through odor and taste intervention; prevention and treatment of obesity by drinking more water; health effects of iron and copper in drinking water; and risks to people over 50 for unhealthy over-exposure to iron in water.

So when Amanda Sain arrived as an environmental engineering graduate student at Virginia Tech, and she started reaching out to faculty, she found the public health element of Dietrich's work fascinating. In turn, Dietrich was able to secure funding for Sain's studies, using resources from the Institute for Critical Technology and Applied Science (ICTAS) and the Water INTERface Laboratory at the Blacksburg, Va., University.

Sain's main project with Dietrich has focused primarily on a specific aspect of human health – what is the impact of exposure to manganese in water and air.


Photo by Jim Stroup

Amanda Sain, right, works with Andrea Dietrich, left, professor of civil and environmental engineering. Dietrich's research includes aspects of cancer therapy, obesity, health effects of certain elements in drinking water, and special risks to people over 50.

According to the Environmental Protection Agency, manganese is naturally ubiquitous in the environment, and exposure to low levels in one's diet is nutritionally essential. However, chronic exposure to high levels of manganese by inhalation in humans may result in central nervous systems effects. Children have exhibited some negative neurological impacts correlated with ingestion of manganese.

The EPA does allow a certain level of manganese in drinking water. To consumers, the permitted 0.05 milligrams per liter might seem non-existent. And interestingly, this amount is mostly for "aesthetic" reasons, Sain noted. This contaminant level was set, reportedly "based on bitter metal-

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Photo by Jim Stroup

Amanda Sain hopes to learn more about the impact to humans exposed to manganese in water and air.

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lic taste, black-brown particles in water, and undesirable black or brown color of fixtures and laundry." But, in actuality, there is not a bitter metallic taste for manganese at that level, Sain and Dietrich revealed in a peer-reviewed journal paper, "Assessing taste and visual perception of Mn (II) and Mn (IV)." Undergraduate researcher Ashley Griffin's name also appears on the article that appeared in the January 2014 issue of the *Journal of the American Water Works Association*.

Mineral content in drinking water "is acknowledged to be the major chemical factor affecting taste and likability of drinking water when no off-flavors are present," Sain and Dietrich wrote. But the problems occur when a mineral such as manganese is not detected by the human senses. They estimated that 50 percent of the population taste threshold for manganese II, the simplest ionic manganese oxide, to be more than 1000 times the current EPA allowable level.

As it is "visually undetectable in drinking water, even at concentrations much greater than those typically found in groundwater…it could lead to ingestion of water with high manganese II concentrations."

With their findings, Sain and her adviser wondered about doubled contamination – water and air. They posed the question of what happens when one inhales a drinking water that is contaminated with manganese. Suppose the contaminated water is used to operate humidifiers in residential homes. The contaminants theoretically could be more than just the manganese, but they focused on this mineral as a starting point.

If the problem in the drinking water goes undetected, and then it is released into the air via the use of humidifiers, is it indeed a threat? If so, their findings could lead to "informed recommendations for the safe use of humidifiers and open the door to looking at water safety not only in the glass, but in the air as well," Sain said.

In the early part of 2014, Sain played an investigative role when the National Science Foundation awarded Dietrich a Rapid Response Grant to determine the overall effect of a chemical spill into the Elk River in West Virginia. In that study, they found that the nature of the chemicals that were released into the water subsequently became a problem with the air quality in nearby residents' homes.

Did you realize that there are more than two dozen flavors to water, not all of which are as yummy as say, rocky road ice cream?

Photo by Logan Wallace

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