

A microscopic image of a starburst structure, possibly a biological or chemical crystal, with many thin, radiating lines. The image is in shades of teal and blue, with a dark background. The lines are most prominent in the upper half of the image, where they appear to converge towards a central point.

UNIVERSITY OF MANITOBA  
**ResearchLIFE**

WINTER 2016 | VOLUME 1

# THROUGH THE LENS

THE MICRO-WORLD  
WHERE BIG IDEAS GROW

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## THE CLEANEST ROOM ON CAMPUS

Where the tiniest machines are made

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## A TRUE RENAISSANCE MAN

The structure of matter is rock solid

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## NEW TWIST IN AN ANCIENT FIGHT

Removing bacteria's defense

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# MESSAGE

FROM THE VICE-PRESIDENT  
(RESEARCH AND INTERNATIONAL)



Materials are in everything we do and touch, from drug interactions and delivery systems to natural materials to microscopic components in everyday electronics. In this issue of Research Life you will learn about some of the

exciting contributions our researchers are making to the materials and materials processing sector of our economy.

The feature story highlights the new state-of-the-art characterization facility and infrastructure housed within the Manitoba Institute for Materials on the Fort Garry campus. An institute that fosters networking and engagement among researchers in different disciplines and is a foci of collaboration within the university and with other institutions and industries in the Prairie region, has evolved from the virtual to reality.

From characterization of minerals to materials physics, nanomaterials, biomaterials, bioprocessing, advanced manufacturing, microelectronics, sensors and medical textiles, university researchers are collaborating with local, national and international colleagues, industries and governments to improve materials and processes used in aerospace, health, biomedical engineering, manufacturing and sustainable resource processing.

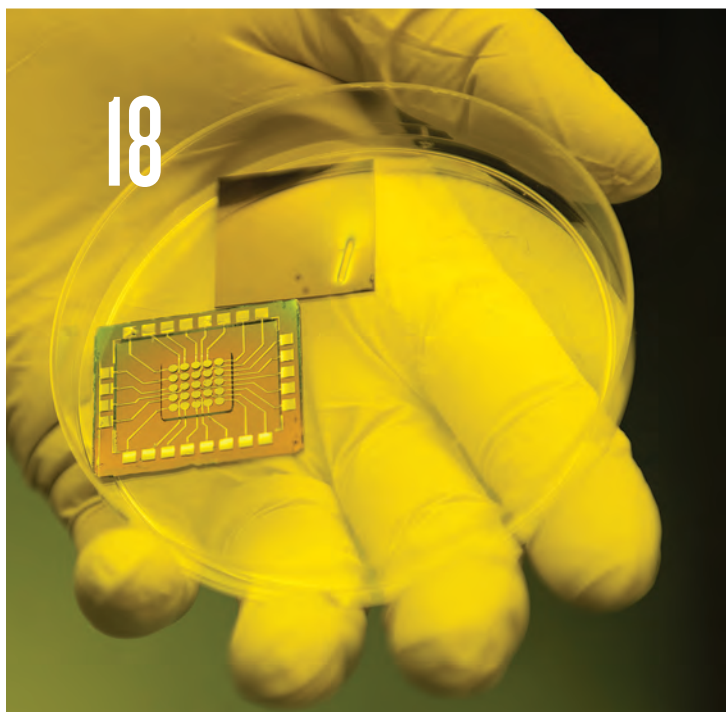
Researchers in this area are also creating innovative technologies that conserve resources, reduce harm to the natural environment, and create a healthy built environment for all Canadians.

—Digvir S. Jayas, PhD, PEng, PAg, FRSC

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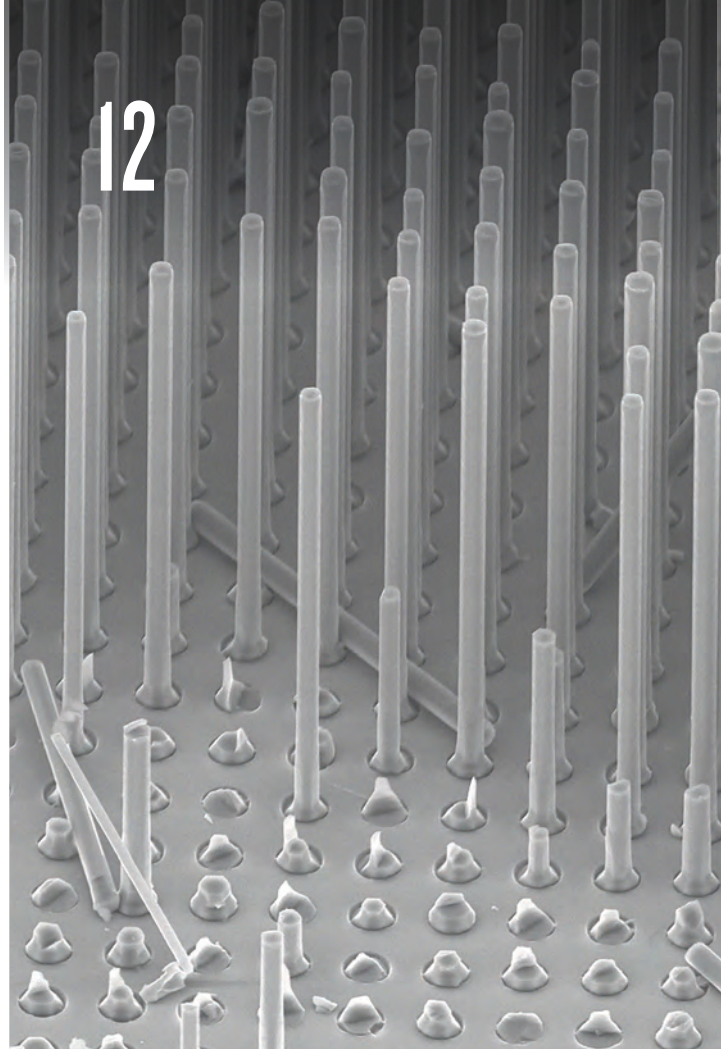


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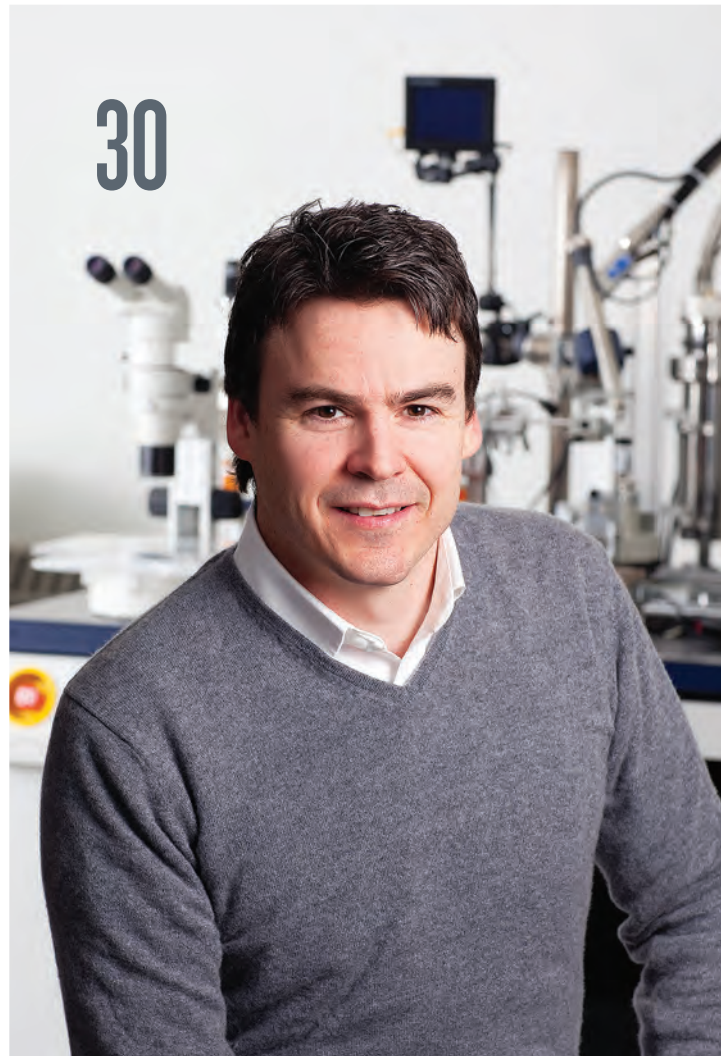




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On the cover: Crystals of the protein NagZ grown by Veronica Larmour (*Brian Mark's lab*)

## ResearchLIFE

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## YOUNG LEADER



**Doctoral student Rebecca (DeLong) Dielschneider was recognized by BIOTECCanada—the biotech industry’s 200 member national association—with the prestigious Gold Leaf Award as a Young Leader in Biotechnology Research.**

Dielschneider’s doctoral research is in the department of immunology at the University of Manitoba’s Faculty of Health Sciences and focuses on lysosomes as targets in leukemia. She does her research at the Research Institute of Oncology and Hematology, a joint institute of the University of Manitoba and CancerCare Manitoba.

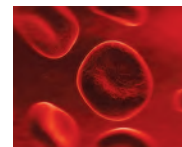
“An important competitive advantage for Canada’s biotech ecosystem is its array of strong regional biotech clusters located in every province of the country, most of which find at their centre a Canadian university. The University of Manitoba’s Rebecca Dielschneider’s ground-breaking research focused on cancer of the immune system embodies the strength of Canada’s young research community and the post-secondary institutions that support

them,” says Andrew Casey, President and CEO BIOTECCanada.

“Rebecca’s work gives Manitoba an even greater reason to be proud of its life science industry,” says Tracey Maconachie, President of the Life Science Association of Manitoba. “She represents the future. Her research is cutting-edge, creative and inspiring.”

Dielschneider was involved in student government and leadership as she pursued graduate studies. She chose immunology and cancer research because she wanted to help people from “behind the scenes.” She believes scientific research allows her to think creatively and pursue answers to tough biological questions, advancing medicine and improving human health.

When asked what she likes most about doing research, Dielschneider said “That’s hard because there are a lot of fun parts but I think my favorite part would still be lab work. The thrill of making a complex experiment work and getting the results that you actually hypothesized. It’s just a thrill and excitement like no other... There’s no other feeling like that!”



**Dielschneider’s** doctoral research is in the department of immunology at the University of Manitoba’s Faculty of Health Sciences and focuses on lysosomes as targets in leukemia. She does her research at the Research Institute of Oncology and Hematology, a joint institute of the University of Manitoba and CancerCare Manitoba.



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## THE BEST IDEAS


Three University of Manitoba researchers are recipients of \$3.7 million from the newly awarded health research Foundation Grants from the Canadian Institutes of Health Research.



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Tracie Afifi, Community Health Sciences

These grants provide long-term support for Canada's research leaders to undertake innovative and high impact programs of research.

Tracie Afifi (community health sciences) will undertake research on preventing child maltreatment in order to improve their health and strengthen families. Lisa Lix (community health sciences/George & Fay Yee Centre for Healthcare Innovation/Manitoba Centre for Health Policy) will conduct research that advances the science of data quality for health outcomes. Jitender Sareen (psychiatry) leads research that will define the course, outcomes and treatment needs of vulnerable Canadians with posttraumatic stress disorder. 



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## NEW MARINE RESEARCH BASE

On July 6, 2015 the Canada Foundation for Innovation, with Manitoba Premier Greg Selinger, visited Churchill, Manitoba to announce an investment of \$22.1 million to build the Churchill Marine Observatory (CMO), a multi-disciplinary research facility where researchers will study the impact of oil spills in sea ice as well as investigate issues facing Arctic marine transportation.

The observatory will be a globally unique, highly innovative, multidisciplinary research facility located in Churchill, adjacent to Canada's only Arctic deep-water port. The observatory will position Canada as a global leader of research into the detection, impact and mitigation of oil spills in sea ice. It will directly address technological, scientific, and economic issues pertaining to Arctic marine transportation, oil and gas exploration and development throughout the Arctic.

When it opens in 2017, the CMO will give researchers unprecedented insight into the Arctic ecosystem and how we can protect it when oil spills during extraction and transportation.

Arctic System Science and Climate Change is one of the U of M's Signature Research Areas, and the CMO is a shining example. "It really confirms the world-class status of our group here," says Distinguished Professor David Barber, Canada Research Chair in Arctic-System Science in the Clayton H. Riddell Faculty of Environment, Earth, and Resources, and head of the CMO project.

The facility will include an Oil in Sea Ice Mesocosm (OSIM), an Environmental Observing (EO) system, and a logistics base. OSIM will consist of two saltwater sub-pools designed to simultaneously accommodate contaminated and control experiments on various scenarios of oil spills in sea ice. The EO system will be located in the Churchill estuary and along the main shipping channel across Hudson Bay and Strait. The EO system will provide a state-of-the-art monitoring system and will be used to scale process studies conducted in OSIM to Hudson Bay and the larger Arctic environment. The logistics base will underpin all CMO research. 



## PATIENT FOCUSED HEALTH RESEARCH


A cluster of researchers are working on newly funded (\$5.9 million) health research projects to study how lifestyle and biological factors influence chronic disease in addition to how digestive systems work, how chronic conditions develop and how to improve care for patients with chronic lymphocytic leukemia (CLL).

“The team/cluster research model brings together dedicated mentors and experts from various fields and encourages participants to explore a wider range of responses and treatments for chronic diseases that affect many Manitoba families,” said Provincial Jobs and the Economy Minister Kevin Chief. “This is a model that has worked in other jurisdictions and has been shown to create better and more relevant research that benefits patients more quickly.”

The DEVOTION project, led by Jonathan McGavock (pediatrics and child health, Children’s Hospital Research Institute of Manitoba) will seek answers to the origins of chronic diseases in children.

The Manitoba Personalized Lifestyle Research (TMPLR) Program – led by Canada Research Chair in Functional Foods and Nutrition Peter Jones, will implement a cross-sectional program to identify the complex interactions that exist between lifestyle, genetics and gut microbiota and explore how these relate to risk factors for chronic conditions.

An innovative cancer research model: Integrated multidisciplinary CLL research cluster—led by Spencer Gibson (immunology, Research Institute of Oncology and Hematology)—will integrate epidemiology, clinical research, and basic science towards improving the outcomes for CLL patients.

A new Manitoba Dementia Research Chair was awarded to Benedict Albeni (pharmacology & therapeutics; St-Boniface Hospital Albrechtsen Research Centre). The chair is will receive \$500,000 in funding from Research Manitoba and the Alzheimer’s Society of Manitoba. Albeni’s research will focus on differentiating between and better diagnosing the two most common forms of dementia: Alzheimer’s disease and vascular dementia. 


## PERFECTING RAMEN

A boil-yourself package of “instant noodles” is a staple food of all late-night crammers and survivalists. And it’s about to get better. Food science researcher Martin Scanlon and his team were awarded nearly \$543,000 in funding from the Natural Sciences and Engineering Research Council of Canada to help Manitoba wheat manufacturers boost Asian noodle production and improve Asian noodle manufacturing processes.



Scanlon and his team will collaborate with manufacturer VN Instruments to develop a prototype acoustic sensor system that will make rolling sheet manufacturing processes more efficient. In addition, the Canadian International Grains Institute will provide Scanlon and his team access to a functional pilot scale noodle manufacturing line to test the acoustic sensor system. The system will initially be applied to measure the properties of noodle dough sheets.

Over half of Canada’s wheat exports are used to manufacture Asian noodles. New knowledge gained from the research will enhance economic activity in a sector that is a major source of foreign revenue.

Scanlon explains: “Our technique allows us to measure online in real time how that mechanical dough development affects the properties of the dough sheet. The objective of the project is to feed that information back to the rollstands during sheeting so that we are continuously adjusting the manufacturing process with a view to optimizing quality of the noodles.” 



Katie Chalmers-Brooks

**Issiah Lozada**, a fourth year chemistry student, collaborates with CIC and researcher Kevin McEleney.

## COMPOSITE COLLABORATION

BY STEPHANIE FEHR

**T**HE COMPOSITES INNOVATION CENTRE (CIC) has been a key player in spurring economic growth and developing innovative new materials for industrial applications since its inception in 2003.

Lighter, stronger, cheaper. Used in many products including planes, construction materials and sporting equipment, composites are reinforcing fibres, such as fiberglass or carbon, which are embedded in plastic materials and are generally more efficient than other materials.

CIC is a not-for-profit corporation, jointly sponsored by private industry and government. It works with industry and academic partners to develop composite materials that perform better than traditional manufacturing materials.

Until 2011, it was located at the university's Smart-park, after which is moved into a 20,000 s.f. facility off campus. The collaborations between CIC and university researchers has been a defining feature.

One of the most recent collaborations is a project between FibreCITY, a division of CIC, and the university's Manitoba Institute for Materials (MIM). This past summer Issiah Lozada, a fourth year chemistry student, working with his advisor Kevin McEleney, helped the CIC evaluate the properties of biofibres for use in composites.

"Through FibreCITY, the CIC is looking for natural fibres to use in composite materials," says McEleney. "These are cheaper and lighter than glass fibres or carbon fibres. The problem with them though is that they are not reproducibly grown, so the batch to batch variation is high. We've been asked to develop ways to characterize these fibres so we can start thinking about

how we might apply that fibre into the end application."

McEleney and Lozada studied four fibres that are grown in Manitoba: linen flax, linseed flax, fibre hemp and grain hemp.

Lozada carried out the day to day work on the project, measuring the samples using a small angle X-ray scattering (SAXS) technique to determine the size and shape of the substructures in the fibre, and using a mathematical model to analyze the fibres.

"Right now the biofibre field is kind of in its infancy in terms of the composites world," says McEleney.

**"Hopefully, more collaborations will come up in the future, and students will have the opportunity to experience them."**

"They need to figure out ways of grading their fibres (for end use). This technique will be one of those ways."

Collaborations like this allow students to gain valuable research experience. "We're looking at publishing this work, so for a student like Issiah, if you can get a publication in during your undergrad, that's a huge step forward, especially if he wants to go to grad school," says McEleney.

For his part, Lozada found the experience challenging and rewarding. "This was the first time I've worked with SAXS and I had to learn the mathematics involved by myself and not in class with a professor," he says. "It was definitely a great experience, especially learning new things from different people. Hopefully, more collaborations will come up in the future, and students will have the opportunity to experience them." ■

A composite is a reinforcing fiber, such as fiberglass or carbon, embedded in a plastic material. The overall engineering performance of a composite is far superior to the individual materials used in isolation. Common uses of composites include aircraft assemblies, body panels on buses, fiberglass boats, reinforcements in civil structures and house construction.

Winnipeg is home to the largest manufacturer in Canada of composite aerospace assemblies and numerous companies that produce composite parts for a variety of applications: from ground transportation vehicles to farm equipment; storage containers and caustic fluid handling systems, reinforcements for bridges and buildings, furniture and environmental technology products.



# ESTEEMED SCHOLARS



LEFT:  
**Zahra Moussavi**  
(biomedical engineering),  
new fellow of the  
Canadian Academy  
of Engineering.

BELOW:  
**Estelle Simons**  
(pediatrics and  
child health,  
CHRIM). New  
Royal Society of  
Canada fellow.



**THREE NATIONAL SOCIETIES** recently elected seven professors to their ranks. New fellows of the Canadian Academy of Engineering are: Zahra Moussavi (biomedical engineering), Nariman Sepehri (mechanical engineering), and

Abraham (Quan) Wang (mechanical engineering). They were elected by their peers for their distinguished achievements and career-long services to the engineering profession. Fellows are committed to ensuring that Canada's engineering expertise is applied to the benefit of all Canadians.

Professor James Davie (biochemistry and medical genetics, and cell biology) is now a fellow of the Canadian Academy of Health Sciences

**Election to the RSC is considered the highest honour an academic can achieve in the arts, humanities and sciences.**

(CAHS). Davie is a world-renowned investigator in the field of chromatin and epigenetics and is a scientist at the Children's Hospital Research Institute of Manitoba (CHRIM) and Research

Institute of Oncology and Hematology (RIOH). For decades his studies have profoundly impacted our understanding of the genetics of human disease, human development, and the emerging field of stem cell biology. Membership is considered one of the highest honours for the Canadian health sciences community. The objective of the CAHS is to provide advice on key issues relevant to the health of Canadians.

New Royal Society of Canada fellows are: Fikret Berkes (Natural Resources Institute, Clayton H. Riddell Faculty of Environment, Earth, and Resources), an internationally recognized scholar on the interrelationships between societies and their resources; James Davie (biochemistry and medical genetics, cell biology, CHRIM, RIOH), a pioneer in the field of epigenetics; and Estelle Simons (pediatrics and child health, CHRIM), a world authority on anaphylaxis and allergic diseases. Election to the RSC is considered the highest honour an academic can achieve in the arts, humanities and sciences. **RI**



# LAUDED INNOVATION

Katie Chalmers-Brooks



**A** **MADE-IN-MANITOBA TECHNOLOGY** that gives surgeons non-invasive access to the inner parts of the brain, saving lives and transforming the hospitals of the future is the recipient of the 2015 Ernest C. Manning Principal Award.

U of M alumni Mark Torchia [PhD/01] and Richard Tyc [MSc/94] received the award for their joint development of the NeuroBlate® System. The system allows surgeons to destroy previously inoperable tumors deep inside the brain using the revolutionary tool developed by the duo at the St-Boniface Hospital Albrechtsen Research Centre.

Torchia is currently an associate professor of surgery at the U of M's College of Medicine and the director of the university's Centre for the Advancement of Teaching and Learning. Tyc is vice-president, technology and advanced technology at Monteris Medical, a spinoff company established in 1999 to create groundbreaking neurosurgical technologies.

The inventors received their \$100,000 award at a gala in Saskatoon.

"This award represents years of persistence, a true bench-to-bedside success story," said Grant Pierce, St-Boniface Hospital executive director of research. "This is a proud moment for the St-Boniface Hospital Foundation, which supported this project from its inception to prototype development."

The tool is used by surgeons who begin by drilling a hole in the skull about the size of a pencil. They insert the Monteris NeuroBlate® System MRI-guided laser probe and use real-time data to guide the probe through the brain to the tumor. There, the surgeons can put the probe into the cancerous mass and destroy it from the inside out with a laser. Essentially, this new tool allows surgeons

**"We are extremely proud of our outstanding alumni and congratulate them on this well-deserved national award."**

to cook the tumor with lethal heat that they can control with unprecedented ability. The tumor is destroyed and the healthy surrounding tissue is preserved. It is the only system in the world that allows surgeons to see the tumor in 3-D, providing them with critical information they need to make treatment decisions in the operating room.

"We are extremely proud of our outstanding alumni and congratulate them on this well-deserved national award," said David T. Barnard, president and vice-chancellor of the University of Manitoba. "Their life-saving technology is having a global impact and Manitobans should be proud of the tremendous work being done at the St-Boniface Hospital Albrechtsen Research Centre, the university's long-time research partner." 

U of M alumni **Mark Torchia [PhD/01]** and **Richard Tyc [MSc/94]** are recipients of the 2015 Ernest C. Manning Principal Award, for their joint development of the NeuroBlate® System.



# INSIGHTS: DON BOITSON

**D**on Boitson, is a mechanical engineering graduate from the University of Manitoba [BSc (ME)/86], is Vice President and General Manager of Magellan Aerospace facilities in Winnipeg and Ohio. For more than 85 years, the company has led the aviation and aerospace industry by engineering and manufacturing highly specialized components for aerospace markets, including advanced products for the military defence and space industries. Locally, Magellan manufactures composite structures and engine components for aircraft, as well as rocket systems, satellites, and other proprietary products. Don was born and raised in West Kildonan and joined Magellan in 1988, when the company operated in Winnipeg as Bristol Aerospace Ltd. Don is a leader in the community, serving on a number of not-for-profit boards.







**T**RY TELLING OUR FOLKS at Magellan Aerospace that what they do is “not rocket science.” This kind of talk, used to downplay the difficulty of a task, might just be the corniest joke ever at our place. That’s because, for more than half a century, our Winnipeg plant has been a pioneer in Canada’s space industry.

Once the primary maintenance depot for the Avro CF-100 Canuck, our facility now designs and manufactures one of the most popular scientific research rockets in the world—the Black Brant—as well as composite structures and engine components for military and commercial aircraft.

### INTRODUCING NEW MATERIALS INTO SOPHISTICATED MANUFACTURING IS A CHALLENGE THAT INDUSTRY AND ACADEMIA ARE ADDRESSING TOGETHER THROUGH JOINT RESEARCH, INNOVATION, AND SKILLS DEVELOPMENT.

Aerospace is the world’s fifth largest economic sector and the second largest in Canada when measured against the size of the national economy. Facing increasing global competition, we are succeeding largely by our ability to develop new materials and technology. Only a generation ago, aluminum—a lightweight and inexpensive material—dominated the industry. In fact, at one time, as much as 70 per cent of an aircraft was made of aluminum.

However, in recent years, aerospace engineering has developed composites, alloys, and honeycomb materials in an effort to build “lighter, faster, stronger” aircraft. Advanced carbon fibre composites can be as strong as aluminum and titanium but far less heavy, reducing aircraft weight by as much as 20 per cent. As a result, the industry is increasingly using these materials to manufacture major wing, fuselage, and landing gear assemblies for new Boeing and Airbus aircrafts.

Like commercial airplanes, military defense aircraft are using new and advanced materials

at an unprecedented rate. Magellan is a major Canadian supplier to the international F-35 aircraft program, the largest new military aircraft development ever undertaken. The program will supply globally more than 3,000 aircraft through 2036. Magellan’s Winnipeg facility, the largest of our 18 plants around the world, manufactures components of the F-35 stealth fighter using advanced carbon fibre composite materials and new, specialized equipment.

Introducing new materials into sophisticated manufacturing is a challenge that industry and academia are addressing together through joint research, innovation, and skills development.

Magellan has worked closely with universities and colleges for years; during the initial phase of composite horizontal tail production for the F-35 aircraft, we collaborated with local educational institutions, industry organizations,

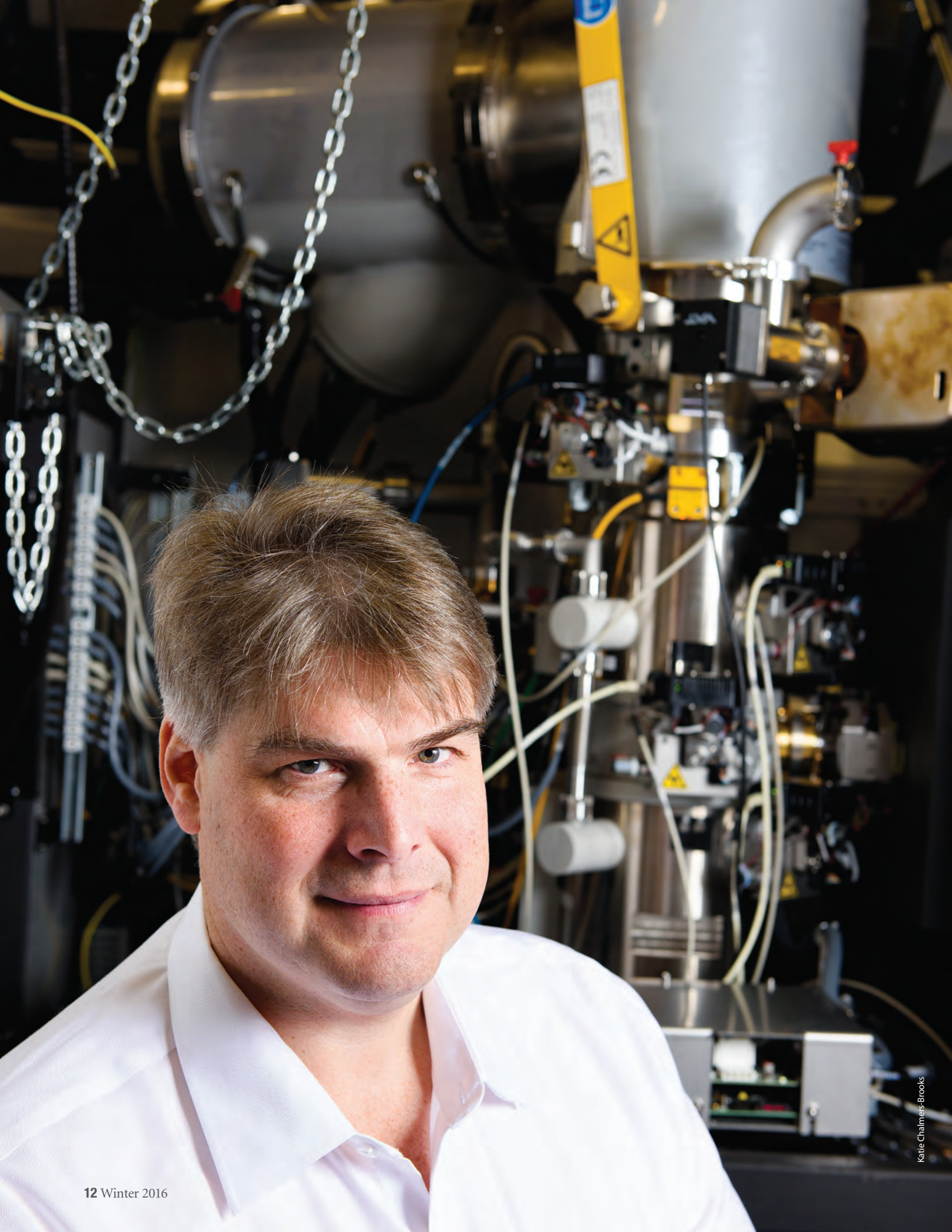
and government to overcome the challenges associated with adopting this technology.

Also, our Winnipeg site hosts the Centre for Non-Destructive Inspection Technologies (CNDI) with Red River College, and the Advanced Satellite Integration Facility (ASIF) with the University of Manitoba. The latter opened in March 2015 to support primarily the F-35 program.

We are working with post-secondary institutions to solve design and manufacturing challenges in metallurgy, welding, heat treatment, and other processes. At the University of Manitoba’s Faculty of Engineering, for example, we are creating an Industrial Research Chair in satellite development. Through these partnerships, aerospace manufacturers can drive innovation and stay competitive.

New materials, and advanced manufacturing including additive manufacturing, will continue to evolve, supplanting traditional materials and processes. The Canadian aerospace industry will succeed by continuing to work with academia, research institutions, and governments to adapt to global changes. ■







# THROUGH THE LENS

THE MICRO-WORLD  
WHERE BIG  
IDEAS  
GROW



BY KATIE CHALMERS-BROOKS

Derek Oliver says the word “cool” like he’s just spotted a Lamborghini. What the University of Manitoba scientist caught a glimpse of is the inner mechanisms of a giant microscope. He apologizes for the “nerd moment” mid-tour of the renovated space that will soon be home to the Manitoba Institute for Materials (MIM). A technician commissioning the Talos™ transmission electron microscope (TEM) left the side panel off, revealing a roadway of cords, and flashing lights and bolted flanges. It’s a view few in the world have seen.

“Is it open?” asks Oliver, jockeying for a view. “Wow. Oh, cool.”

**T**HE MICROSCOPE IS THE FIRST of its kind on Canadian soil and one of only 10 across North America. The \$16.7 million MIM Facility for Composite and Material Characterization, of which Oliver is director, is scheduled to open this winter with this massive microscope as its main attraction.

The device is so sensitive to vibration and electronic noise that the acoustically sealed room where it’s

housed can’t have fluorescent lighting (since it emits tiny amounts of radiation) and the operator has to control the machine remotely from outside. The microscope’s specifications fill a binder four inches thick, and include parameters as specific as how much the ambient temperature can deviate over an hour.

**THE MORE SCIENTISTS KNOW ABOUT THE MOLECULAR MAKEUP OF COMPLEX MATERIALS—BE THEY ROCK, METAL, PLANT OR PLASTIC—THE BETTER THEY CAN BRING ‘THE NEXT BIG THING’ TO LIFE.**

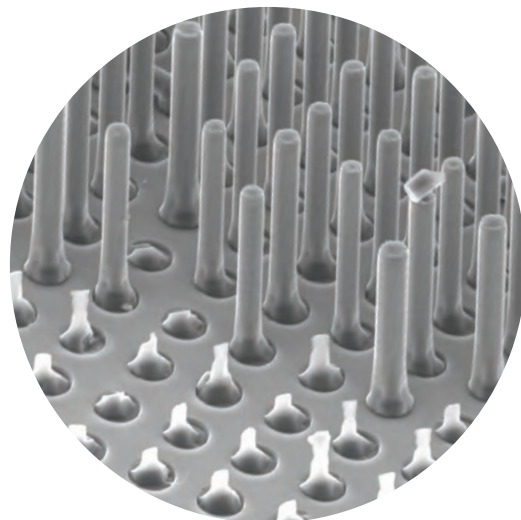
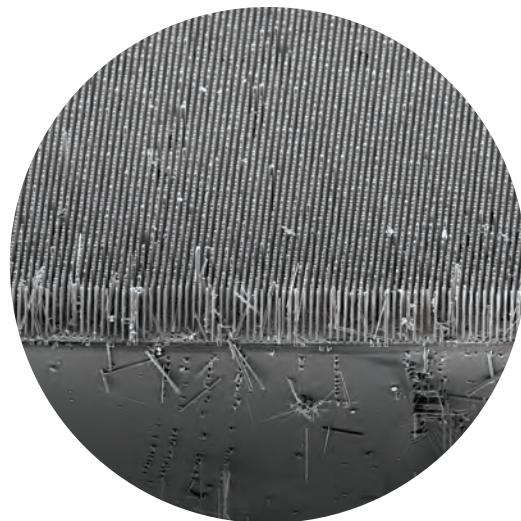
To the layperson, the microscope looks like a futuristic vending machine. To the expert, it is a finely crafted machine that provides incredibly accurate information in 3-D about the spacing of atoms in a sample.

The more scientists know about the molecular makeup of complex materials—be they rock, metal, plant or plastic—the better they can bring ‘the next big thing’ to life.

“Materials are at the core of our modern life,” says Oliver, an associate professor in the department of electrical and computer engineering.



**Derek Oliver,**  
director, Manitoba  
Institute for  
Materials

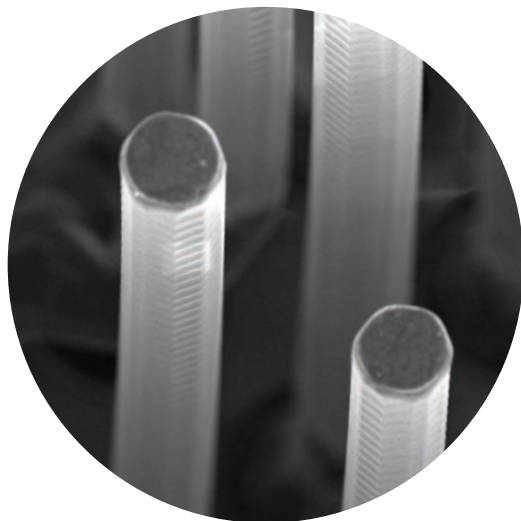


Cross-section of silicon rods 1.5–2.5 micrometers i.e. 1/40 to 1/30 the diameter of a human hair.

TOP: Image represents 5–10 human hair diameters.

MIDDLE: Entire image is roughly the width of a human hair.

BOTTOM: Entire image is about 1/10 of the width of a human hair.





Indeed, materials research is in demand from industry players looking for ways to improve on everyday items, from the pan we cook with to the cellphone we can't live without.

These new technologies can shape entire sectors, as is the case for aerospace in Western Canada. Some of MIM's researchers look at new ways to build and test airplane parts to make them stronger yet lighter, which saves on fuel. More than \$3 million of the facility's funding comes from the federal government's Western Economic Diversification Program and General Electric to boost Winnipeg's aerospace industry.

To develop high-tech composite materials, scientists must uncover how its molecules and the atoms within are constructed, how they're linked together, what geometric shape they form. The more they figure out, the more they realize how much they don't yet know.

"It's one of those slightly funny, almost paradoxical things, that you suddenly realize in a sense how little you actually do understand," says Oliver. "Maybe you're looking at materials we have used for years and years and years and we're still discovering new information. . . This new information enables you to develop a new product or a better product or a new technology."

The University of Manitoba formed MIM six years ago. The group is made up of researchers from the Faculties of Engineering, Science, Health Sciences, and Agricultural and Food Sciences, as well as the Clayton H. Riddell Faculty of Environment, Earth, and Resources.

Their area of focus runs the gamut, from engineering new materials that build stronger bridges, to developing the next generation of memory technology for our computers, to using ultrasound to develop the perfect ramen noodle. (Over half of Canada's wheat exports are used to manufacture Asian noodles.)

"This is a massive market impact," says Oliver. "It's a neat illustration of the kind of connectivity that we're trying to build more of."

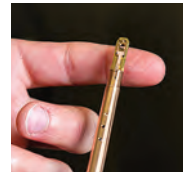
Often facilities are developed around one high-profile researcher but in this case, it's a multi-million dollar investment in a collaborative approach, bringing together more than 200 faculty, researchers and students university-wide. "This facility breaks the mould because it is an institutional investment," says Oliver.

To get to the materials research hub, you have to go deep underground: 17 steps below the tunnel beneath Allen Building. It will also have a ground-level entrance in a building-cum-island in the parking lot known as A-Lot, 25 Sifton

**"WE'RE STILL DISCOVERING NEW INFORMATION. . . THIS NEW INFORMATION ENABLES YOU TO DEVELOP A NEW PRODUCT OR A BETTER PRODUCT OR A NEW TECHNOLOGY."**

Road. What for years was a space that stored physics equipment—a decommissioned cyclotron—is now reimagined into a modern mix of instrument rooms and lab space.

Welcome to the land of the little, where the size of a sample is described by how much smaller it is than a human hair. Each of the centre's three new, world-class electron



**Kevin McEleney**, the MIM facility manager, prepares a sample for testing.



microscopes have their own unique talent and will be used by researchers in different ways.

Take the environmental scanning electron microscope, which can analyze wet or living samples (even a house-fly). Because it requires less of a vacuum, the samples can be examined in their natural state. Geologists can image permafrost—frozen cores of rock, soil or sediments—and their surfaces to see embedded microfossils and better understand and predict global warming. Biological scientists can image the molecular makeup of plants destined to be environmentally friendly plastic.

"We have a lot of plant matter around because we are on the Prairies and there are bits of industry along these lines that we can tap into and want to tap into," says Oliver.

He's collaborating with researchers at Caltech and the Florida Institute of Technology to build and modify small rods of silicon. They're among a large network of labs whose end goal is to develop a device that could use sunlight to

## FEATURE

split water into its constituent parts: hydrogen and oxygen. Hydrogen could solve the energy needs of developing countries, and, closer to home, oxygen could be generated for medics to give to patients in remote Manitoba communities.

**WHEN IMAGED CLOSE-UP**, these rods resemble tire marks left from a driver doing doughnuts in a desert. Another view looks like an aerial shot of a depleted lumberyard. A third, Oliver notes, reminds him of the kid's toy that takes the shape of your hand when you press against its plastic spindles. The images can look striking, even beautiful.

A close-up of metal fibres on the NanoSEM scanning electron microscope could be confused for abstract artwork. "Each of these dots is about one two-thousandths of the width of a human hair," says 6-foot-2 Oliver.

Researchers from the Composites Innovation Centre (a not-for-profit industrial consortium with whom MIM partners) will use the electron microscopes to analyse naturally grown fibres that offer a more sustainable option to fibreglass. Alongside researchers from biosystems engineering and chemistry, they're investigating if plant fibres could replace glass fibres to manufacture wing and engine components for planes. (They've already shown local manufacturer Buhler-Versatile a tractor hood and fender made of hemp and agave fibres.) These composites would be as strong as metal but much lighter.

**"EACH OF THESE DOTS IS ABOUT ONE TWO-THOUSANDTHS OF THE WIDTH OF A HUMAN HAIR," SAYS 6-FOOT-2 OLIVER.**

College of Dentistry researchers are looking at ways to make dental coatings and fillings last longer. And agriculture researchers are investigating which fungi grow on grain during its storage—in developing countries, where as much as half of harvests can be lost to spoilage.

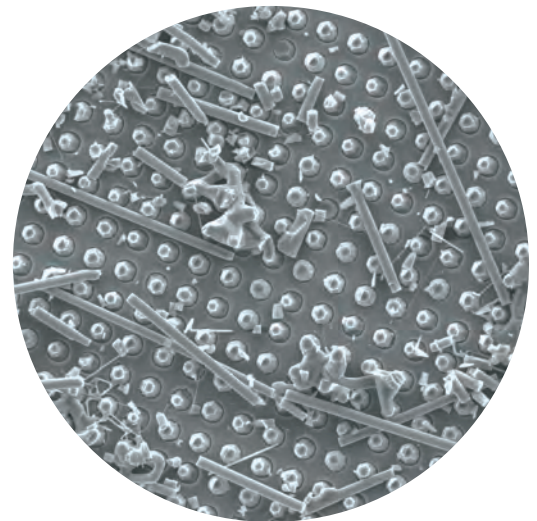
"Not only are we showing to the outside world how something that might normally sit in the research domain could be useful to them, but we're showing the students we graduate how the leading edge of research technology can be relevant to different parts of the world," says Oliver.

Students will learn alongside researchers and industry partners. From the communal area in the heart of the 9,000-square-foot centre, they can check out imaging from the TEM microscope as it happens.

These details matter, insists Oliver. The facility is designed for collaboration and to encourage students to learn by doing.

He points out another detail in the new space—the frosted design on the many glass walls. These series of lines depict a spectrum. Oliver explains it's a nod to spectroscopy (the study of how matter can be 'fingerprinted') and how sunlight is filtered by the atmosphere. Symbolically, this décor touch brings natural light down into the windowless basement space.

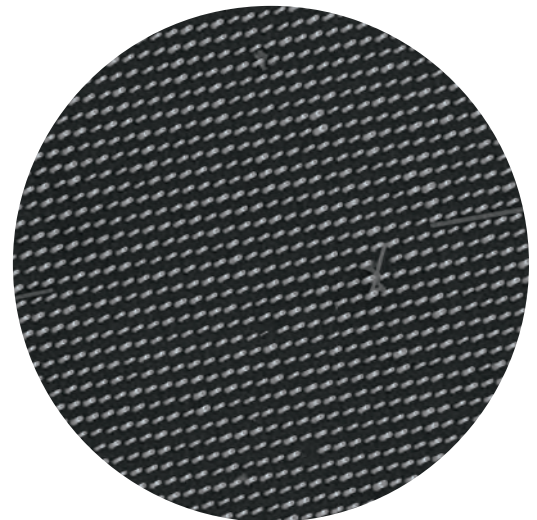
"It's kind of a fun, little thing," he says. 



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TOP: Entire image represents 1–1.25 human hair diameter.

RIGHT: Entire image represents 1.5–2 human hair diameter.



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The training facility classroom affords easy access to the equipment and fosters collaboration.

Photo: Katie Chalmers-Brooks





# BIO-IMAGING: PRINCIPLES, TECHNIQUES, AND APPLICATIONS

## HIGHLIGHTS THE EMERGENCE OF IMAGE PROCESSING IN FOOD AND AGRICULTURE

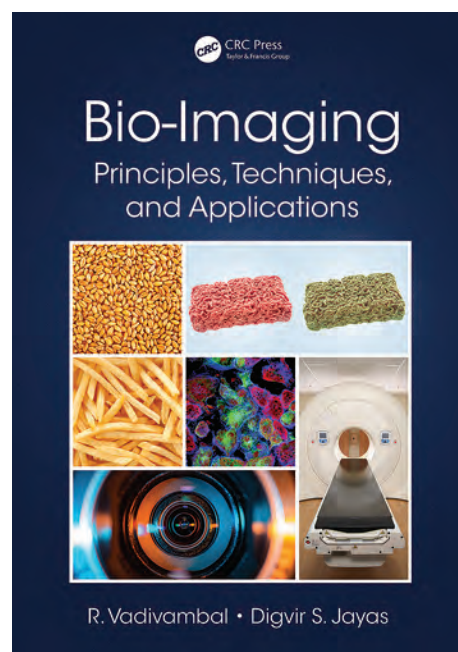
**“In this book, mainly agriculture and food applications are covered with few medical applications... Extensive chapters on six specialized imaging techniques and their applications in [the] food and agricultural sector ...Image acquisition methods, image analysis, and classification methods are explained elaborately in an easy-to-follow manner.” – DR. ANNAMALAI MANICKAVASAGAN, SULTAN QABOOS UNIVERSITY**

### **I**N ADDITION TO USES SPECIFICALLY

related to health and other industries, biological imaging is now being used for a variety of applications in food and agriculture. **Bio-Imaging: Principles, Techniques, and**

**Applications** fully details and outlines the processes of bio-imaging applicable to food and agriculture, and connects other bio-industries, as well as relevant topics. Due to the noncontact and nondestructive nature of the technology, biological imaging uses unaltered samples, and allows for internal quality evaluation and the detection of defects. Compared to conventional methods, biological imaging produces results that are more consistent and reliable, and can ensure quality monitoring for a variety of practices used in food and agriculture industries as well as many other biological industries. The book highlights every imaging technique available along with their components, image acquisition procedures, advantages, and comparisons to other approaches.

- Describes essential components of imaging technique in great detail
- Incorporates case studies in appropriate chapters
- Contains a wide range of applications from a number of biological fields



RAJAGOPAL VADIVAMBAL AND DIGVIR S. JAYAS (CRC PRESS, 2015)

**Bio-Imaging: Principles, Techniques, and Applications** focuses on the imaging techniques for biological materials and the application of biological imaging. This technology, which is quickly becoming a standard practice in agriculture and food-related industries, can aid in enhanced process efficiency, quality assurance, and food safety management overall.

## ABOUT THE AUTHORS:

Distinguished Professor Digvir S. Jayas is the vice-president (research and international) at the University of Manitoba. He has authored or coauthored more than 800 technical articles in scientific journals, conference proceedings, book chapters, and conference papers. Jayas has collaborated with researchers in several countries, and has had a significant impact on the development of efficient grain storage, handling, and drying systems in Canada, China, India, Ukraine, and the United States.

Vadivambal Rajagopal is a post-doctoral fellow at the University of Manitoba. She holds a doctoral degree in biosystems engineering from the University of Manitoba and a bachelor's of agricultural engineering from Tamil Nadu Agriculture University, Coimbatore, India. In her research career, she has published in national and international journals more than 15 research papers related to grain quality, grain storage issues, microwave drying and disinfestation, and thermal imaging. She has presented research articles at many national and international conferences and has authored chapters in books related to the food and agriculture industry. **RI**

**THE**

**CLEANEST**

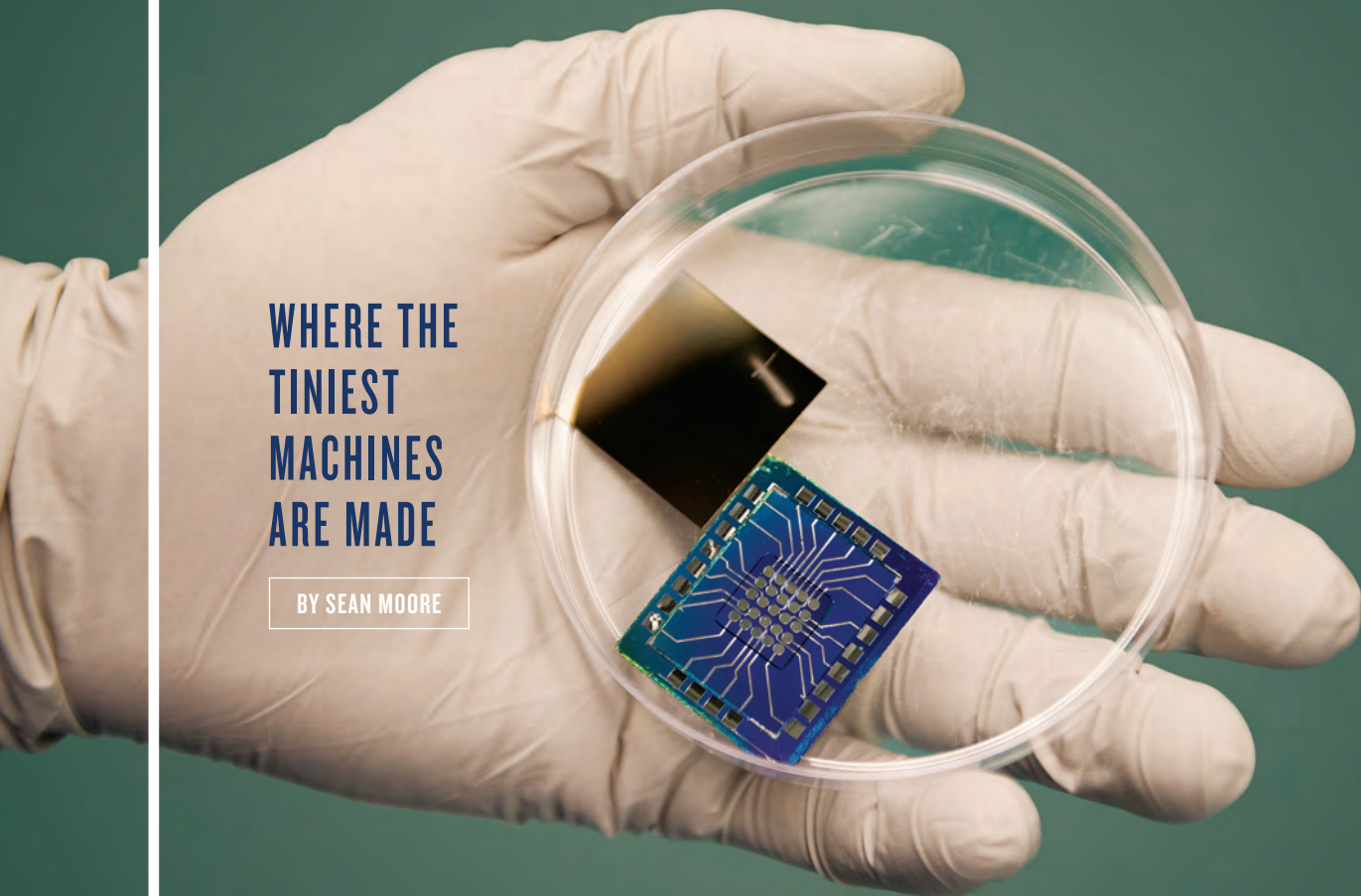
**ROOM**

**ON**

**CAMPUS**

**WHERE THE  
TINIEST  
MACHINES  
ARE MADE**

**BY SEAN MOORE**







Cyrus Shafai went against his instinct. He knew he probably didn't have to buy the small wood sticks to apply the silver glue he was purchasing from the scientific catalogue, but he was a cautious graduate student and thought the sticks might have some special quality. Perhaps they were super clean.

“

**ORDERED THEM EVEN THOUGH**

I was pretty sure they were just toothpicks. Then they arrived and I looked at them and thought they looked exactly like toothpicks. So I put one in my mouth and it tasted like mint. I bought expensive toothpicks,” the renowned nano material researcher admits.

This lesson stayed with Shafai throughout his research career in the Faculty of Engineering: buy local and build what you can yourself, and invest the savings elsewhere. In 2001, he was looking to purchase an ultra-clean lab, but instead his team decided to build one instead.

## FEATURE

That year, three technicians from Electrical and Computer Engineering drove to the University of Alberta to disassemble a clean lab that Micralyne Inc. was scrapping. The parts were loaded onto three freight trucks, and shipped to Winnipeg. Then, Shafai, his students, and the technicians began re-assembling the lab, making trips to Canadian Tire and other hardware stores to purchase parts. The lab has since grown into the Nano-Systems Fabrication Laboratory, a key part of the Manitoba Institute for Materials (MIM).

“A lot of time universities put a higher value on the professors,” Shafai says, “but the technicians also have skills that are of high value – they build things and are crucial in training students.”

Interestingly, the purchase of a household-grade washer and dryer to clean the special suits people must wear required some explaining.

“That raised some flags,” Shafai says laughing. “You can order very expensive machines, but a washer and dryer on a purchasing order looks weird.”

**T**HIS SPECIALIZED LAB is the only facility of its kind in Manitoba and one of only a handful in Canada. With over \$4 million of equipment it's a central facility in the university's material research network.

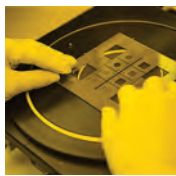
Dust has no home here: visitors must wear lint-free suits and the lab's air is exchanged entirely several times every minute. Even the paper researchers write on is not actually paper but a plastic, since scratching a pen on paper creates dust. It's quite possible the cleanest air one will ever breathe. “It's great in allergy season,” Shafai says.

Under the roar of ventilating fans, he researches and builds micromachines, or micro-electronic-mechanical systems, specialized devices used in many areas of life – cars rely heavily on them; your airbag is controlled by one.

They are tiny. A dust particle dwarfs their components, which is why the lab must be so clean. At this scale, a colliding dust particle can destroy what Shafai and his students built.

Shafai builds micromachines that bend mirrors, sense electrical currents, and make small antennas act like big ones – a project he works on with his father, U of M professor Lotfollah Shafai.

“I think my biggest success has been in developing the techniques to build these micro structures,” Shafai says. “Every time we make something we learn something new and then we bring that skill set to make another design. If you came to me 10 years ago and said lets make adaptive optic mirrors, I'd say 'No.' But now we have technology that we can tackle the problem. We've been working on this for three years and it looks like we can build a functional one.”



High resolution stencil mask used for UV lithography process.

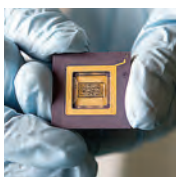
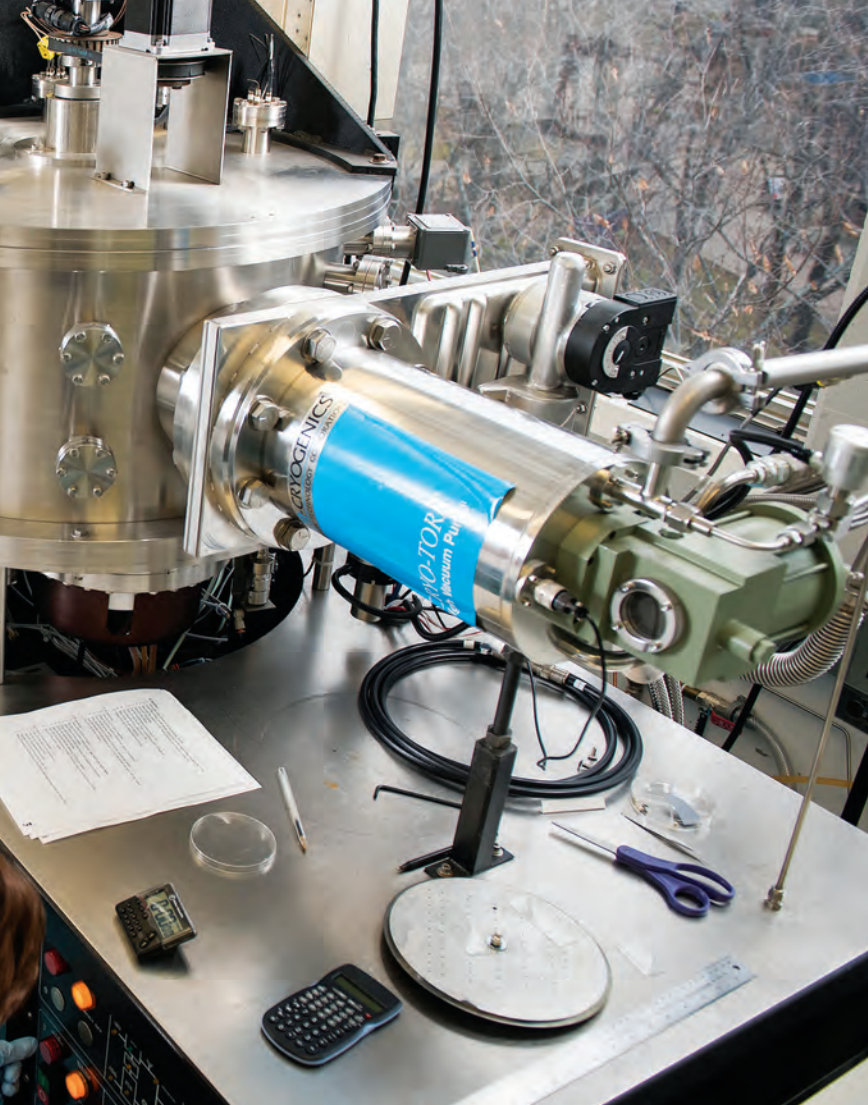
**TOP:** Counter-clockwise: Graduate students Sampath Liyanage, Valerie Beynon, and Byoungyoul Park operating the sputter system cluster tool (used for material coating).

Adaptive optics was conceived by astronomer Horace Babcock in 1953. Babcock wanted to solve a problem tormenting his field – twinkling. Stars twinkle because turbulence in the atmosphere distorts their light. Through an Earth-based telescope they look fuzzy, offering little useful information. Babcock thought-up adaptive optics and today engineers like Shafai have cultivated the knowledge to build the advanced technology.

**“I THINK MY BIGGEST SUCCESS HAS BEEN IN DEVELOPING THE TECHNIQUES TO BUILD THESE MICRO STRUCTURES. EVERY TIME WE MAKE SOMETHING WE LEARN SOMETHING NEW AND THEN WE BRING THAT SKILL SET TO MAKE ANOTHER DESIGN.”**

How it works: a laser mounted to a telescope shoots into the sky and a computer notes how the light distorts, hundreds of times a second. This information is used to instantly move hundreds of actuators under a dime-sized mirror. The actuators act like pistons, constantly pushing and pulling the surface of the mirror, altering its shape to counteract the atmosphere's turbulence. Voila, astronomers get a clear view, something normally reserved for space-based telescopes like Hubble.





Packaged chip containing several magnetic field micro-sensors.

This technology can also be used to help image the retina in human eyes, where image quality is affected by aberrations when trying to look inside the eye. Adaptive optics can correct this and allow doctors to see parts of the eye much clearer.

But common adaptive optics systems need a lot of voltage to move the actuators, and each is hooked up to its own wire, resulting in thousands of wires running from the machine to an external power source resulting in an expensive and relatively bulky, inelegant, contraption.

Shafai improved this design in two ways. First, he made the mirrors bigger and out of polymer rather than metal, making them more flexible and thus lowering the energy needed to warp them. But the big change was using tiny, low voltage magnetic actuators.

Working with U of M Physics and Astronomy professors Jayanne English and Jason Fiege, Shafai micromachined a system wherein small coils run under the mirror segments. When electricity runs through the coil, the magnetic field generated pulls the mirror segment down. This method uses far less voltage and far fewer wires. In fact, Shafai can build the mirror and the circuitry onto the same chip, opening the possibility of mass-producing them quickly and cheaply.

“So that’s our adaptive optics system,” he says. “We’re hoping it works. We’ve done the design work already and this year we

**“WE ALL HAVE OUR SKILL SET. FOR MANY PROJECTS YOU NEED ANOTHER PERSON TO BRING SKILLS YOU DON’T HAVE. MIM, I THINK, HELPS BRING EVERYONE TOGETHER. YOU BECOME AWARE OF THE EXISTENCE OF CAPABILITIES THROUGH MIM.”**

have been trying to build some prototypes in the lab.”

The Nano-Systems Fabrication Lab, however, does more than just build tiny machines.

Nearly 300 different professors and students have used the lab. It is an open-access facility, where you can rent time on machines by the hour. Want to put a gold coating on a wafer? You can get it done here. The lab also has one of the most sophisticated chemical areas on campus and Shafai encourages others to use it rather than spend the time and money setting up their own.

“We all have our skill set,” Shafai says. “For many projects you need another person to bring skills you don’t have. MIM, I think, helps bring everyone together. You become aware of the existence of capabilities through MIM. You might not have otherwise known that in that building over there they can do these cool things.”

TOP RIGHT: Shafai with Valerie Beynon.

BOTTOM RIGHT: Shafai observes Yu Zhou (PhD candidate) operating the UV lithography mask aligner.

# DIGITIZING NOVEL APPROACHES BETWEEN DESIGN AND FABRICATION

BY JASON HARE



**Jason Hare**  
is the manager/  
researcher at  
the Faculty of  
Architecture's  
FABLab.



Casting of photo-  
grammetrically  
captured  
landscape.

Joseph Visser



**M**OST INDIVIDUALS CAN identify with the taxonomic definition of Homo sapiens, 'the wise.' Though with the advent of technology come new tools that allow individuals to reach out beyond themselves and connect with the world in novel ways. These tools act as a lens to see the world through, a lens that challenges normative standards of practice and methods in which daily lives unfold. Digital fabrication is one such lens.

The relationships forged between the mind, the body and the tool is one of great interest to myself. In the past decade there has been an explosion of digital tools introduced to the design disciplines that have had a large impact on the conceptualization of forms. These tools have taken on a variety of forms ranging from computational language structures, software modelling methods and computer numerically controlled fabrication devices. All of which have suggested future methods of construction, some novel and some novelty. I am specifically interested in processes that have the potential to manifest themselves as working methods in the field of design and construction. The excitement in any technology driven environment is the ability to move novel away from novelty, and towards unique methods which empower individuals in their given fields of study.

**I am deeply invested in meaningful interactions with technology and researching the ways in which digitally driven tools can seamlessly interface with existing methods of design while pursuing novel means of fabrication.**

a level of play is required to uncover what potential overlaps are hidden within each agent. Once uncovered these are then cultivated as meaningful ways of communication between designers, fabricators and builders.

The caesium that used to exist between the digital drawing and the materialized form continues to collapse into a narrow gap that allows for the direct translation between digital space and the physical fabrication of material. With this collapse it has become critical for designers to understand the capabilities of rapid prototyping equipment as a means of conceptualizing form and not just the production of formal concepts. In this case the interest lies within the tool as an agent of formal concepts that play an active role in the final outcome.

Finally, I am deeply invested in meaningful interactions with technology and researching the ways in which digitally driven tools can seamlessly interface with existing methods of design while pursuing novel means of fabrication. In an earnest effort to uncover the sapien 'the wise', faber 'the maker' and ludens 'the player' of all agents within the realm of digital fabrication, consisting of both human and machine. ■

My research lies between the fundamental agents that help digitize the material and materialize the digital. Without attempting to work between the physical and digital realm, it becomes exceedingly difficult to imagine digital geometry as a physical material and ultimately move beyond the screen. As most of the tools in the digital fabrication lab are cross-disciplinary,

**Living Hinge:** Realizing doubly curved surfaces in sheet material.



**Photoluminescent:** Playing with material characteristics of clear resin.



**FAR RIGHT: Bridge:** Exploring half-lap jointing in bridge construction.



**Digital to Physical:** Casting molds with the assistance of additive manufacturing.



**Education:** Working one-on-one with students to explore methods of digital fabrication.



**Time lapse model:** An assembly of fabricated parts used to communicate the effect of time.





# TRUE RENAISSANCE MAN

BY CHRIS RUTKOWSKI





## FRANK HAWTHORNE'S RESEARCH ON THE STRUCTURE OF MATTER IS ROCK SOLID

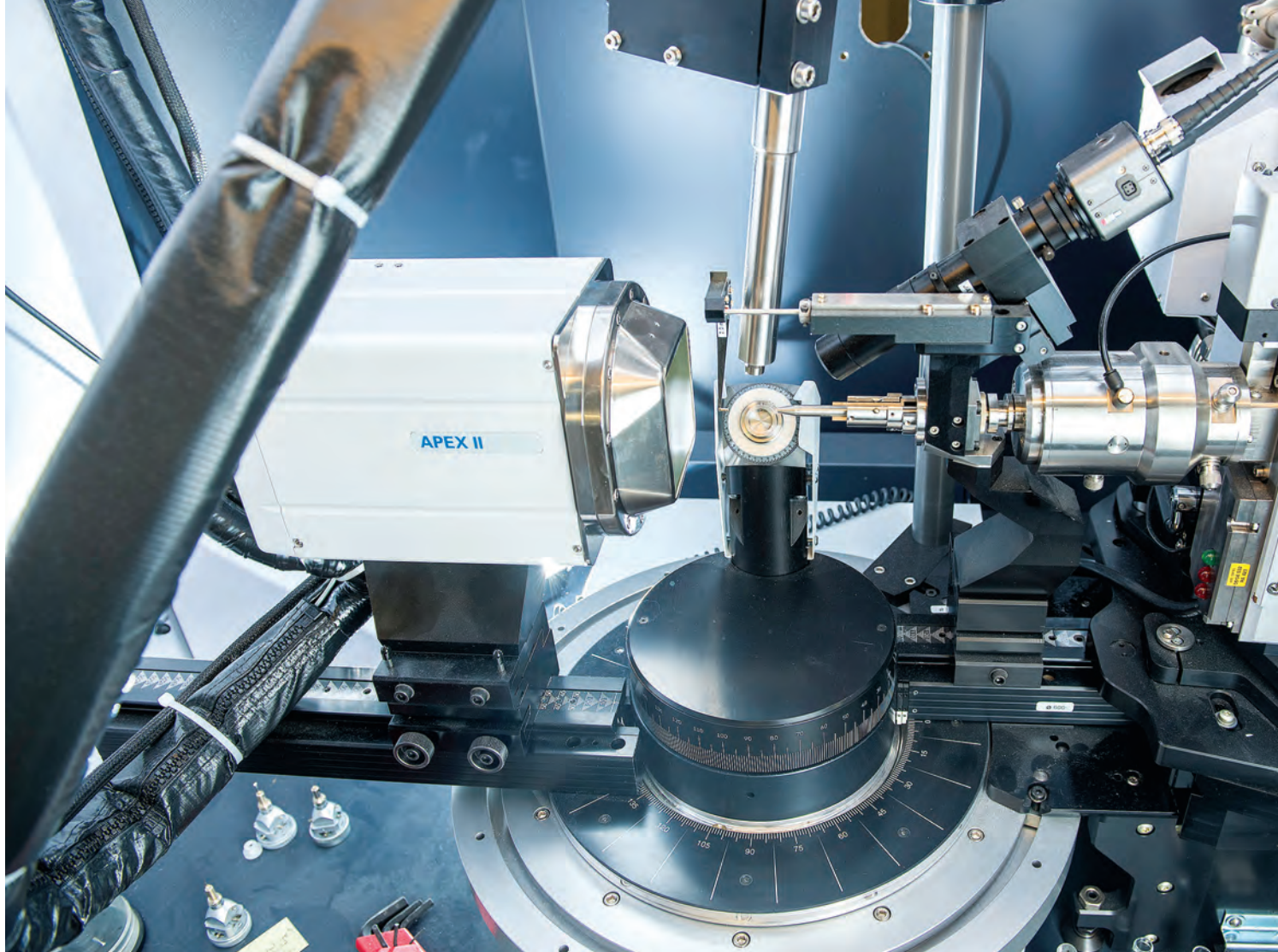
There's an art print hanging prominently in the office of Frank Hawthorne, tucked away in a back hallway on the fourth floor of the Clayton H. Riddell Faculty of Environment, Earth, and Resources. The title is *Knight at the Crossroads*, painted by Russian artist Viktor Vasnetsov in 1878. It currently hangs in The Hermitage in Moscow, a gallery Hawthorne has visited half a dozen times.

“

**T MADE AN IMPRESSION ON ME,**” says Hawthorne. “The knight has a choice which way he wants to go: one way to the farm, and the other to the battle-field.” He adds: “I was thinking about retirement when I saw that.”

Almost 70, Hawthorne's career has taken him to the pinnacle of his field, having achieved prominence few others can claim. In 2007, Thomson Scientific, a leading information company, analyzed data from 150,000 scientific papers published between 1997 and 2007, noting that Hawthorne was the most-cited geoscientist in the world, with 2,204 citations during that period alone.

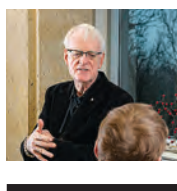
“I hadn't realized there were that many,” he says modestly.



Hawthorne was born in England in 1946, trained at the Royal School of Mines, Imperial College in London, and then at McMaster University in Hamilton. He was a post-doctoral fellow and later held a Natural Sciences and Engineering Research Council of Canada (NSERC) University Research Fellowship (URF) from 1980-1990 at the University of Manitoba. In 2001 he was appointed Canada Research Chair in Crystallography and Mineralogy and is now distinguished professor in geological sciences.

**H**AWTHORNE HAS BEEN described by students and colleagues as a “rock star” because of his work in geology, of course. In fact, he takes the joke in stride; his office is adorned with posters of Pink Floyd, The Who and The Rolling Stones. He admits that he’s a fan of early rock and is fascinated by the history of “beatniks” like himself.

This may seem in sharp contrast to someone who is an Officer of the Order of Canada, a Fellow of the Royal Society of Canada, a Foreign Member



Geological sciences student Jeremy Deyholos working with Hawthorne in the lab.  
Photo: David Lipnowski

## “HOW DO ATOMS COME TOGETHER TO FORM SOLIDS, AND CAN WE MANUFACTURE OR DESIGN NEW MATERIALS BY ARRANGING ATOMS DIFFERENTLY?”

of the Russian Academy of Sciences and someone who has received a multitude of awards for his scientific work, including the Killam Prize in Natural Sciences.

The “rock” designation is somewhat ironic because Hawthorne’s work has little to do with a chunk of granite from the Rockies or a pebble found on a beach. His research instead focuses on understanding the atomic structure of minerals, using advanced mathematical concepts such as topology and graph theory to determine how materials are assembled at the atomic scale.

In fact, his desire to quantify the atomic structure of minerals was what led to his invitation to become a Foreign Member of the Russian Academy of Science, an honour bestowed on very few. He was giving a talk in Moscow when the vice-president of the Russian academy heard him and admired his quest to inject rigorous mathematics into the geological sciences. Hawthorne was soon elected to the academy because of his work on the foundations of mineralogy.

“It’s an accolade that completely outdoes everything else,” Hawthorne notes.





David Lipnowski

That in itself is remarkable because Hawthorne has achieved such respect in his field that a mineral has been named after him: *frankhawthorneite*. (It's a rare, green, copper-based mineral discovered in Utah in 1995.)

Hawthorne is personally interested in solving a problem that seems basic to all branches of science: "Why is that the way it is?" he wonders: "How do atoms come together to form solids, and can we manufacture or design new materials by arranging atoms differently?"

### "I WANT TO UNDERSTAND THE CHEMICAL COMPOSITIONS AND ATOMIC ARRANGEMENTS OF MINERALS."

He points to solid state electronics that are doped with various atoms to modify and improve their characteristics, and modern high-temperature ceramics that have been developed in the laboratory to make them usable in the average home oven.

"I want to understand the chemical compositions and atomic arrangements of minerals," he explains. "Studying three-dimensional arrangements of atoms is fascinating to me."

Hawthorne says his research isn't confined to his laboratory or calculations with matrices. He believes firmly in interactions with other researchers around the world.

"It's not just going to conferences and presenting or listening to others lecture," he says. "It's talking with others and getting to know them and their work."

"Café conversations are the best," he says, smiling.

And then, there's his non-work time, which he values highly.

"I need time by myself, just to think," he notes. He's spent much time in museums and art galleries around the world, like the Russian Museum in St. Petersburg in which he was enraptured by *Knight at the Crossroads*. He enjoys Renaissance and Baroque art and has spent enough time in Italy that he's "almost fluent" in Italian. He appreciates opera and other artistic works such as sculpture and poetry.

"An artist can reach out and speak to me," Hawthorne says poignantly. "I can look at a painting by Caravaggio and it seems as though he's talking directly to me."

Hawthorne may have found the ideal balance between science and art. He may deal with abstract mathematics, but he can envision the formulae creating physical structures and materials that can be used or appreciated by others.

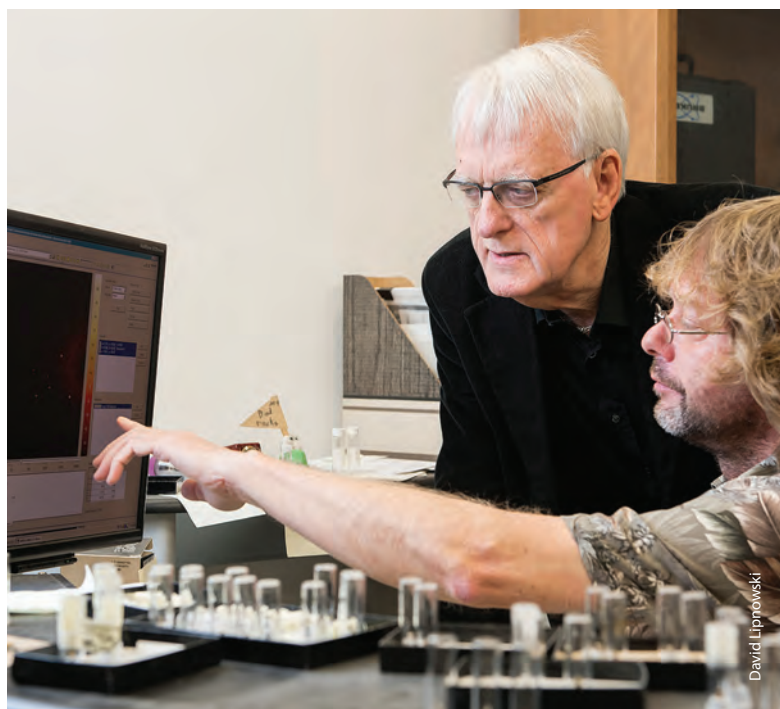
"Science doesn't have the personal aspect that is inherent in art," he states, "because science is a collaborative and collective activity."

"But both are intellectually satisfying," he adds. ■



*Knight at the Crossroads*, painted by Russian artist Viktor Vasnetsov in 1878

TOP: A rotating-anode single-crystal diffractometer.



David Lipnowski

Technician Mark Cooper viewing results with Frank Hawthorne.

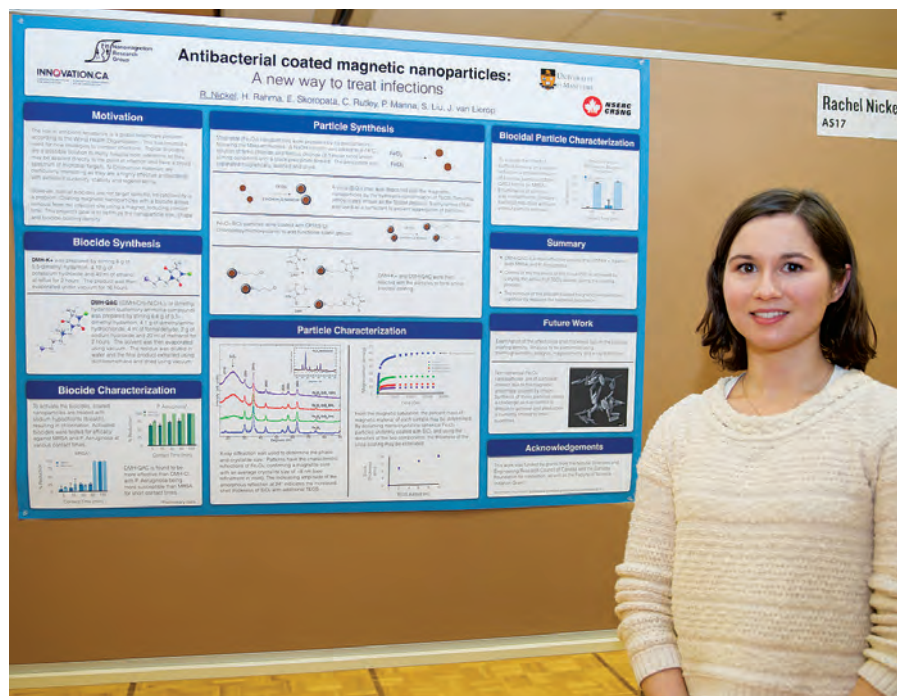
Photo: David Lipnowski

# SPOTLIGHT ON UNDERGRADUATE STUDENT RESEARCH

BY ERIC POSTMA

**A** SHOWCASE OF UNDERGRADUATE student's expertise and passion for research, the Undergraduate Research Poster Competition is an annual event that takes place in the fall at the University of Manitoba. The competition offers \$5,000 in cash prizes in five categories: applied sciences, creative works, health sciences, natural sciences and social sciences/humanities. The event gives undergraduate students the opportunity to present research they've conducted with their advisors over the past year. The breadth and variety of research is significant.

Two of the undergraduate students who competed this year conducted their research related to this issue's materials research theme.



## RACHEL NICKEL

### Tell me about your research project.

I looked at antibacterial-coated magnetic nanoparticles and the purpose of this is to treat surface wounds. It helps remove the need for systematic antibiotics.

### What about this project appealed to you?

It's cool! It's really fascinating because we're looking at nanomaterials which don't behave anything like bulk materials. As soon as you scale down you get all these unusual properties that start showing up.

### What do you really love most about the project?

I really enjoyed the time I was in the chem lab just working on synthesis, seeing things happen. [I loved] to see all the colour changes that happened and run it under [X-Ray Diffraction] to see the changes, and to see under [Scanning Electron Microscope] that we had made what we actually wanted to make.

### What was the process like making the poster?

I was really lucky because a lot of the

**Rachel Nickel**, fourth year undergraduate student studying biomedical physics

photo: Mike Latschislaw

material had already been brought together. I found putting the words together a little more of a challenge, especially paring down the words. There is so much stuff that you want to talk about!

### What would you say to another student who is thinking about getting involved in research?

Do a summer project because it is an awesome opportunity where you get to see what research is.



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## IAN BURRON

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**Tell me about your research project.**

We looked at two uranium deposits in Nunavut. We were hoping to find a better method of locating uranium deposits.

**How did you get involved in this project?**

I went up to meet [Mostafa Fayek] and the first thing he did after shaking my hand was ask, “Have you filled out the paperwork? Can we do this?” He had been sitting on this project for a while; he just hadn’t had the time to devote to it. I thought it was really interesting, so he put me on it and that’s what I did for most of the summer.

**What about this project was interesting to you?**

It aligns quite nicely with what I want to do. When I graduate I want to go into mineral exploration and this is a project to develop a new means for mineral exploration.


**What part of the project did you really enjoy?**

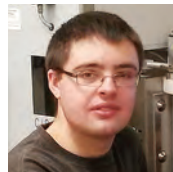
The actual machine is interesting because it loads your sample into the furnace with a little robotic arm and then the arm unloads this fully molten, glowing rock sample out of the furnace and dumps it into the little bin and picks up a new sample. It is interesting to watch that, and while you are doing this you are watching your results start coming in.

**What was the process like making the poster?**

It was challenging. It’s easy to throw something together quickly, but to put something together that you are proud of it takes a lot of time, a lot of planning and a lot of tinkering.

**What would you say to another student who is thinking about getting involved in research?**

Ask around the faculty, get to know your professors and put it out there that you might be interested in doing these kinds of things. You would be surprised what kind of opportunities you can find if you put your name out there and start meeting people. 



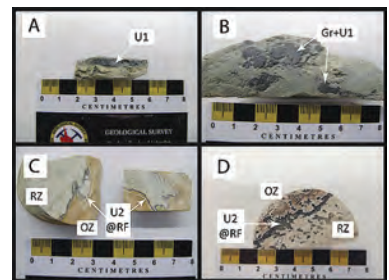
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**Ian Burron,**  
third year undergraduate student  
studying geology.



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TOP: The CS ELTRA  
machine used in  
Burron’s research.



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TOP AND MIDDLE  
RIGHT: Samples  
of uranium ore  
Burron worked  
with. The black  
veins are  
uranium oxide.

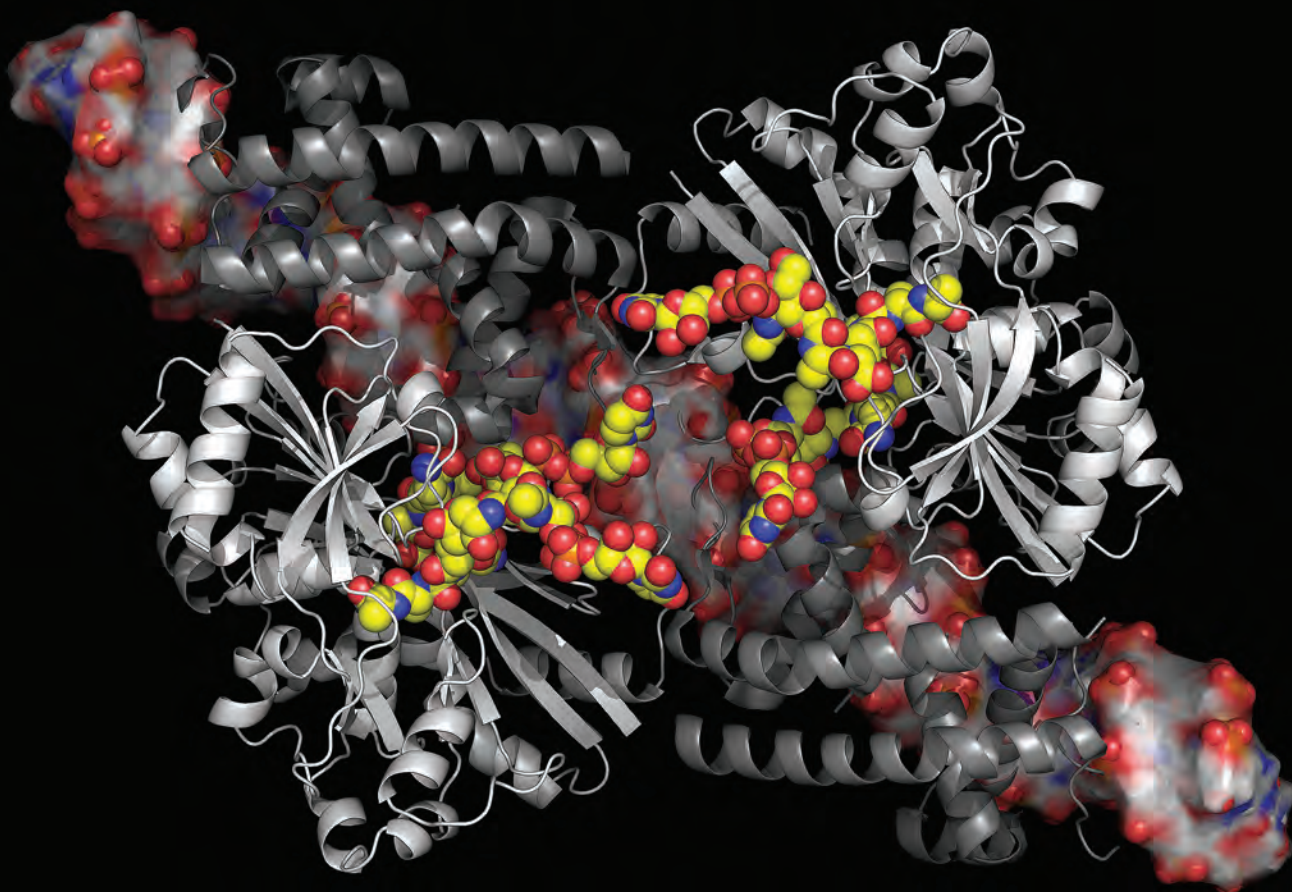


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BOTTOM RIGHT:  
Powdered rock  
sample prepared  
for analysis in  
the ELTRA.

# NEW TWIST IN AN ANCIENT FIGHT

BY SEAN MOORE





# REMOVING BACTERIA'S DEFENCE GIVES US A NEW OFFENCE

We can't win, so we're trying not to lose. Since the late 1980s we've struggled to find or build new weapons to use in our ancient fight against bacteria and now bacteria are developing resistance at an alarming rate to the drugs we have.

**G**LOBAL HEALTH agencies publish a frightening number: in 35 years, if left unchecked, antibiotic-resistant bacteria will kill 10 million people annually across the globe. For those keeping score, that's two million more than cancer.

One microscopic foe is *Pseudomonas aeruginosa*. It evolved in soil, which looks benign to our eye but is actually a surprising bed of microscopic violence and struggle. For 3.5 billion years bacteria have fought to survive here, developing new defences and weapons every generation, which for bacteria is about every 20 minutes. As a result, bacteria today are a hearty bunch – *Pseudomonas* notoriously so.

It grew up in this harsh underworld but now lives a relaxing life in hospitals,

infecting lungs and open wounds. Its only combatant is us, we have only a few drugs to fight it, and they are quickly losing potency.

"How is it doing this? How is it defending itself from our drugs? That's what we've been trying to figure out and a key clue comes from the materials it produces," says Brian Mark, an associate professor of microbiology at the University of Manitoba who has dedicated a branch of his research program to fighting this bacterium.

*Pseudomonas* creates a few materials, one of which is a nearly impenetrable outer membrane. Most drugs can't get through it, and if any do, *Pseudomonas*' powerful efflux pumps quickly toss them out. One type of drug that can defeat these systems is beta-lactam. But once inside, *Pseudomonas* detects it and quickly produces a protein to destroy the drug.



**Brian Mark,**  
associate professor  
of microbiology.

OPPOSITE PAGE:  
Molecular model of  
AmpR, a bacterial  
protein that senses  
when certain antibi-  
otics are damaging  
the microbe and  
responds by activat-  
ing production of  
AmpC, an enzyme  
that destroys the  
antibiotic. *Vadla-  
mani G et al (2015)  
J Biol Chem 290:  
2630-2643.*



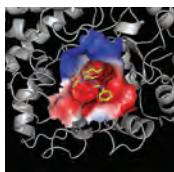
PhD student Ben Bailey-Elkin locates a protein crystal under the microscope that will be harvested and mounted on the X-ray diffractometer to the right in the image. The X-ray diffraction pattern generated by the crystal can be used to determine the 3D atomic structure of the protein.

At this juncture, we have two options. Develop new antibiotics, like U of M microbiologist George Zhanel and U of M chemistry and medical microbiologist professor Frank Schweizer have been doing since 2006. Or, study the materials *Pseudomonas* uses to defend itself to see how we can help existing antibiotics fight better.

**M**ARK'S LAB STUDIES THE structure of defensive proteins *Pseudomonas* creates to find their exploitable weaknesses. His team begins by extracting the proteins and coaxing them to crystallize. Once the protein crystal is sufficiently large, it is brought to an X-ray diffraction machine, which bombards it with X-rays to reveal its atomic structure.

Every protein is built out of a set of 20 different amino acids combined into long and unique chains. Then, crucially, it folds into a specific shape and that shape dictates its function. So when Mark investigates what the protein looks like three-dimensionally, he gains insight into how it works.

"There are always secrets that pop up," Mark says. "When you solve the 3-D structure of a protein you've never seen before, there are always interesting surprises that you can see that you never expected. The solution Mother Nature has arrived at to carry out some function is sometimes completely different than we had theorized. Either the way it folds or the way it interacts with another molecule can be completely different than what we expect. There are always surprises that show up."



The 3D crystal structure of NagZ bound to PUGNAC (yellow), a drug-like molecule that blocks NagZ activity to suppress beta-lactam antibiotic resistance in the bacterial pathogen *Pseudomonas aeruginosa*. NagZ Structure determined by PhD student Ms. G. Vadlamani. For a review see: Mark BL et al (2011) *Future Microbiology* 6: 1415-1427.

In the case of *Pseudomonas*, Mark examines the proteins it uses to activate the production of beta-lactamase, a protein that destroys many of our most cherished antibiotics known as beta-lactams. After solving the 3-D structure of these proteins, his team looks for areas on the protein where small, drug-like molecules can fit.

Once snug in place, the small-molecules designed by Mark and his collaborator professor David Vocadlo, a chemical biologist at Simon Fraser University, block *Pseudomonas* production of beta-lactamase. In short, they took its defence away and in the process showed beta-lactam resistance could be overcome in *Pseudomonas* using such a strategy.

**"YOU NEVER KNOW A PRIORI THE CHEMICAL CONDITIONS THAT WILL GIVE RISE TO A PROTEIN CRYSTAL. THIS CAN BE A STUMBLING BLOCK THAT IS VERY HARD TO OVERCOME."**

This approach is called structure-based drug design: Solve the shape; find the weakness; exploit it. It works well, except the process has one hurdle – it requires scientists to crystallize the proteins they wish to target.

"Often times you put a lot of effort into all the steps and then you run into the problem that you can't crystallize the protein you want to study," Mark says. "You never know a priori the chemical conditions that will give rise to a protein crystal. This can be a stumbling block that is very hard to overcome."



Much to the joy of Mark, one scientist recently opened a new avenue of opportunity in the fight against antibiotic drug resistance: Kim Lewis, from Northeastern University in Boston, who gave this year's U of M's Armes Lecture in the department of chemistry.

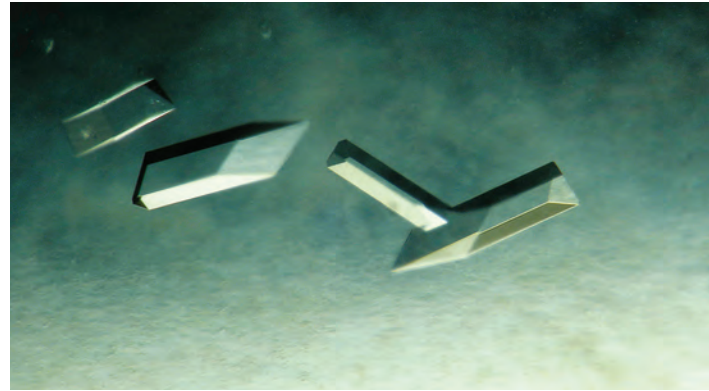
**“THERE IS CONSIDERABLE POTENTIAL TO FIND NEW ANTIBIOTICS FROM ALL OF THESE UNCULTURED MICROBES. IT APPEARS WE’VE ONLY SCRATCHED THE SURFACE.”**

The vast majority of microbes require very specific conditions to grow. To discover new sources of antibiotics – weapons bacteria make to defend themselves from peers – requires us to grow them. But soil, the cradle we want to rob, has a colossal supply of niches for life to exploit. If a soil microbe slides micrometers in any direction, it may occupy a new niche – one with different acidity, moisture or chemical factors, that may not be habitable to it. We cannot replicate this great quantity of environments in the lab.

Thus, Lewis thought up the idea of culturing bacteria in the soil itself. Basically, you put the bacteria you want to culture into a cassette and insert it back into their environment. Whatever factor it needs to grow passes through the permeable cassette walls. The bacteria grow, you retrieve the cassette and study the culture.

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RIGHT: Crystals of NagZ after optimizing growth conditions (Ms. V. Larmour, Department of Microbiology, University of Manitoba). *Stubbs KA et al (2007) J Biol Chem 282: 21382-21391.*



“It’s brilliant,” Mark says. “And he’s now discovered a new antibiotic that works really well against a major class of bacteria. There is considerable potential to find new antibiotics from all of these uncultured microbes. It appears we’ve only scratched the surface.”

Microbiologists celebrate good news like this when they get it, but remain humble because history suggests they should. For instance, on May 15, 1944, as the Allied troops began preparing for D-Day, *Time* magazine published a picture of Dr. Alexander Fleming on the cover with the text: “His penicillin will save more lives than war can spend.” As that cover ran, however, researchers began noticing certain strains of *staphylococci* no longer responded to penicillin.

The next great drug discovered was methicillin in 1959. It was revered, but 11 months later bacteria resistant to methicillin were discovered.

This story repeats over and over again: we find a drug, then we discover bacteria already have a defence against it, one likely developed in ancient times.

“And the resistance mechanisms can be shared among bacteria – this is the real problem,” Mark says. “Some harmless soil bacteria may have a remarkable defense mechanism against an antibiotic we rely on, yet it doesn’t pose a medical risk because it’s not infectious. However, bacteria can share DNA with each other, so if an infectious microbe acquires the mechanism, and then shows up in the clinic, it can become a serious problem.”

This is why Mark’s approach offers such an exciting avenue: design materials to deactivate defences, allowing old drugs to work once again.

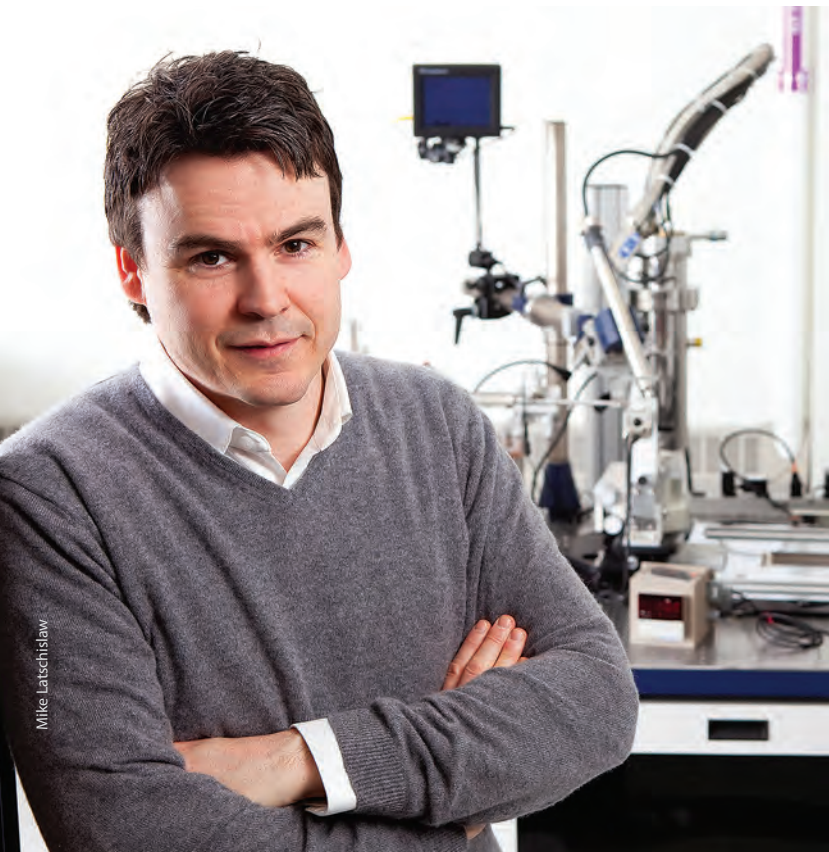
“Bacteria are smarter than us,” Zhanel quips. “They are working very hard to resist and develop resistance to what we are doing. So we are playing catch-up, and our goal is to continue playing catch-up with a variety of strategies.”

By understanding biological materials such as proteins and designing new drugs to block them we may indeed gain the upper hand in the battle against antibiotic drug resistance.

We may not win, but we won’t lose. “Keep in mind that we’re studying the material of Mother Nature,” Mark says. “She’s the master of material science.... We have a lot of challenges ahead.”

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BELOW: Mark in front of the X-ray diffractometer that is used to investigate protein structure in atomic-scale detail.



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# UNIVERSITY OF MANITOBA SPEAKER SERIES

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### JANUARY 20, 2016 - GUT INSTINCT:

THE SCIENCE BEHIND THE BRAIN-GUT CONNECTION

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### MARCH 15, 2016 - MULTIPLE SCLEROSIS:

QUESTIONS AND ANSWERS  
FROM MANITOBA RESEARCHERS

7 p.m. – 8:30 p.m. McNally Robinson Booksellers  
1120 Grant Avenue, Winnipeg

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### FEBRUARY 24, 2016

HAS MANITOBA PUT THE RIGHT VALUE  
ON POST-SECONDARY EDUCATION?

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### MAY 18, 2016

WHAT MORE CAN MANITOBA'S "MOST POWERFUL"  
DO TO OPEN THE DOOR TO DIVERSITY?

Doors open: 6:30 p.m.

Panel Discussion: 7 p.m. – 8:30 p.m.  
Reception: 8:30 p.m. – 9:30 p.m.

Winnipeg Art Gallery, 300 Memorial Blvd

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## BY THE NUMBERS

**64** endowed and sponsored research chairs – including 37 Canada Research Chairs and the highly prestigious Canada Excellence Research Chair

**54** research centres, institutes and shared research facilities

**44** Royal Society of Canada Fellows

**8** National Synergy Awards for Innovation

**5,750** staff (2014/15) – 1,197 full-time faculty; 4,553 support staff

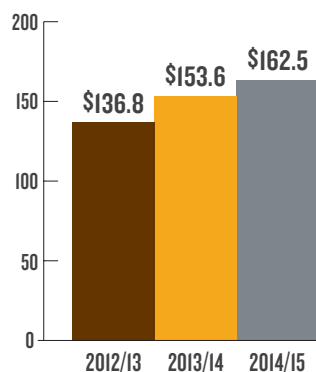
**29,959** students – 25,588 undergraduate; 3,722 graduate

**16.2%** of students are international students, representing 111 countries

**\$701.8** million annual operating budget (2015/16)

### SPONSORED RESEARCH INCOME THREE YEAR COMPARISON (\$ MILLION)

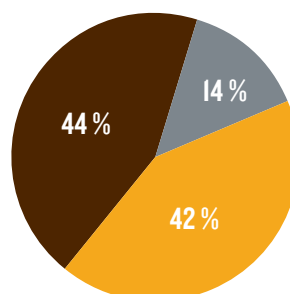
- 2012/13: \$136.8M
- 2013/14: \$153.6M
- 2014/15: \$162.5M



### SPONSORED RESEARCH INCOME BY SOURCE (2014/15)

**TOTAL: \$162.5 MILLION**

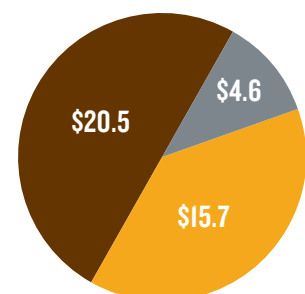
- **FEDERAL GOVERNMENT**  
44 %
- **OTHER**  
42 %
- **PROVINCIAL GOVERNMENT**  
14 %



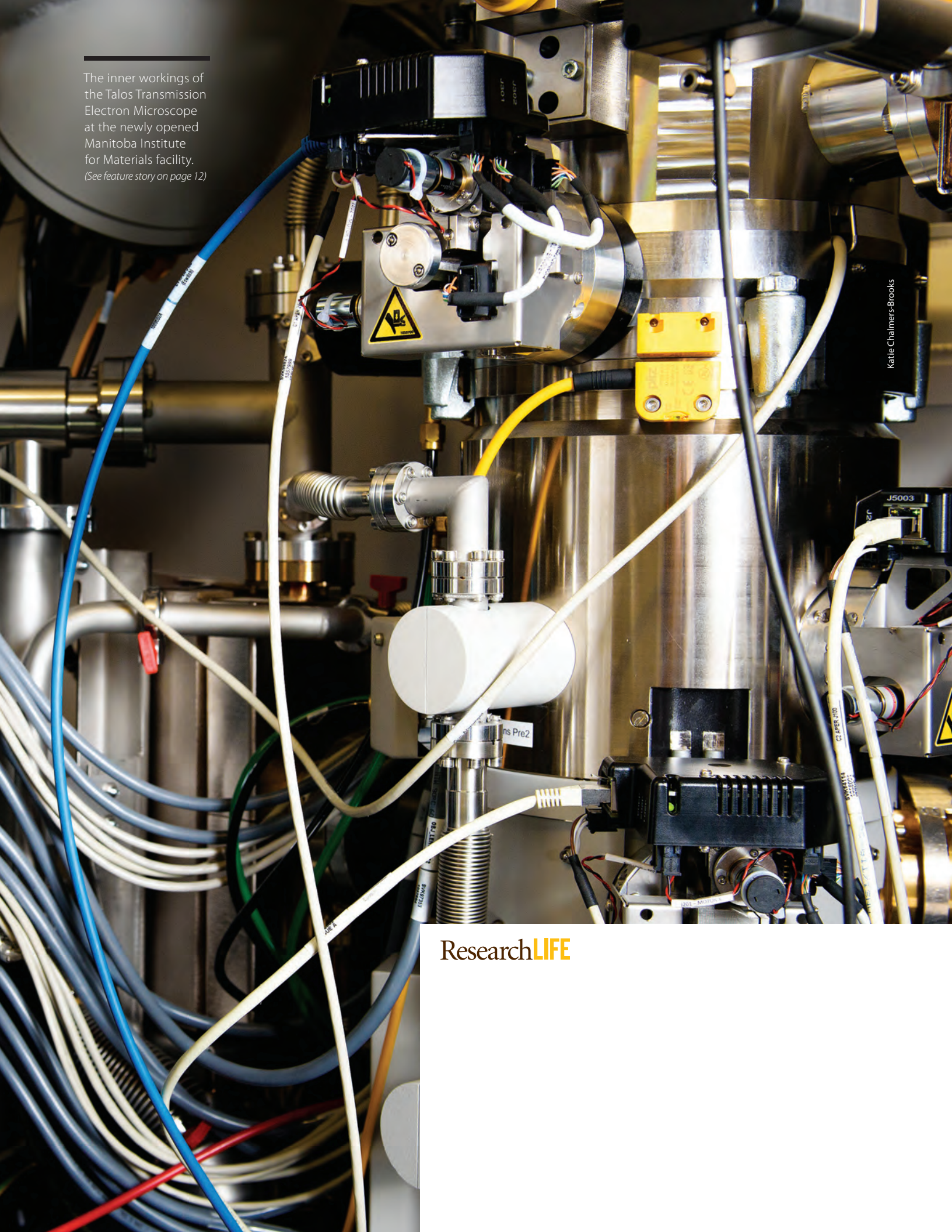
### TRI-COUNCIL FUNDING 2014/15 (\$ MILLION)

**TOTAL: \$40.9 MILLION**

- **CIHR (Canadian Institutes of Health Research)**  
\$20.5M
- **NSERC (Natural Sciences & Engineering Research Council of Canada)**  
\$15.7M
- **SSHRC (Social Sciences & Humanities Research Council of Canada)**  
\$4.6M



The inner workings of the Talos Transmission Electron Microscope at the newly opened Manitoba Institute for Materials facility. (See feature story on page 12)



Katie Chalmers-Brooks

Research**LIFE**