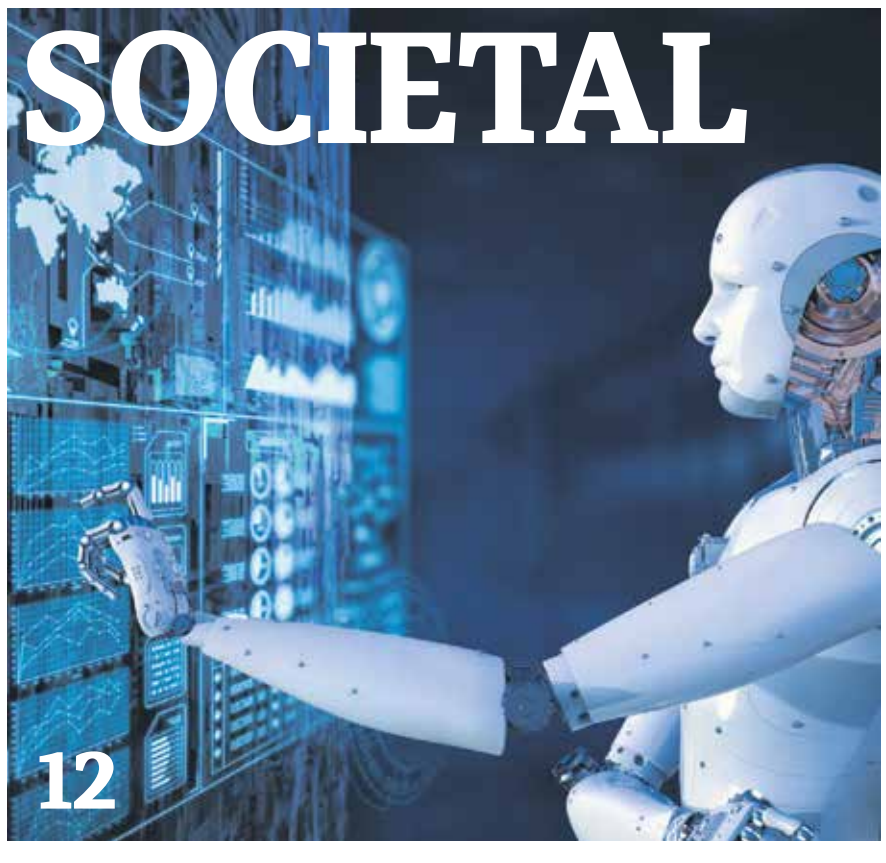
RESEARCH AND INNOVATION



THE ROOT OF INNOVATION

Discoveries transforming lives and livelihoods

IN 2017, CANADIAN EXPORTS OF CANOLA surpassed those of wheat. And yet, in the 1990s, what is now Canada's most valuable crop was almost destroyed.

Blackleg, a destructive fungus that kills cereal crops, had spread quickly, threatening Canada's canola industry. Yield losses in some Western Canadian fields were approaching 50 per cent before Gary Stringam, a University of Alberta (U of A) plant scientist, found a gene in an Australian canola strain that was resistant to blackleg and used it to create a new canola variety called Quantum.

In its first year of production, four Alberta farmers more than tripled their yields with the new variety. A year later, Quantum was being grown on nearly 30 per cent of Western Canada's canola acres. Today, canola contributes more than $26-billion to Canada's economy, supporting more than 250,000 jobs. Canada's canola accounts for nearly 70 per cent of global canola imports.

"Research at Canadian universities is where this kind of work happens," says Matthias Ruth, U of A vice-president of research. "And the University of Alberta is no exception.

"University research is a catalyst for innovation and crucial not just to economic diversification and competitiveness, but also to the lives, health and livelihoods of Canadians, and the country as a whole," says Dr. Ruth.

In fact, according to U15, a collective of Canada's research intensive universities that includes the U of A, $8.5-billion worth of research – accounting for 83 per cent of all contracted private-sector research in Canada – is conducted annually by these universities.

The U of A's history of driving innovation dates back to the early 1920s and the university's infancy, when biochemistry professor James Collip played a pivotal role in the treatment of diabetes by purifying insulin for human use. Fast-forward 80 years, when U of A researchers introduced the Edmonton Protocol, a procedure that saw certain patients with type 1 diabetes become insulin-independent, at least in the short term, at an unprecedented success rate of 100 per cent. While it's not a cure, the protocol is used in Canada, the United Kingdom, Italy and Switzerland. The United States is expected to follow.

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>
> **Dr. Matthias Ruth**
> Vice-president of research, the University of Alberta

State-of-the-art facilities like Alberta Cell Therapy Manufacturing help to advance cell-based therapies from bench to bedside. SUPPLIED

The U of A's discoveries and innovations extend far beyond agriculture and diabetes. Researchers at the university also laid the foundation for lamivudine, the world's first hepatitis B antiviral, now licensed in over 200 countries, which has also proven useful in combating HIV/AIDS. The university also launched Canada's first computer science department. Fifty years later, the U of A is a critical mass of leading artificial intelligence experts, and one of Canada's three national AI hubs. It attracted partners such as Google, Amazon, IBM and the Royal Bank of Canada, and in 2017, DeepMind choose Edmonton as its first international AI research lab, thanks to the expertise at the university.

Whether it's Quantum canola, the Edmonton Protocol or lamivudine, Dr. Ruth says lives and livelihoods depend on transferring technologies out of the lab. That requires a healthy innovation ecosystem which, to thrive, needs consistently strong support for fundamental research.

"Nobody knows whether a great product for which there is a market down the road will ultimately result from research," explains Dr. Ruth. "Just look at lasers, which were called a solution waiting for a problem when they were created in the 1950s. But if fundamental research is not well supported in a healthy and sustainable way, innovation will suffer and decline."

Understanding the vital impact research can have, the U of A partnered with the City of Edmonton in 2006 to launch a business accelerator, TEC Edmonton. Since then, the university's research has spawned hundreds of patents and licences, and has 130 spinoffs still operational.

INNOVATION ECOSYSTEM ADVANCING HIGH-TECH OPPORTUNITIES

THIS MONTH, THE OKANAGAN INNOVATION ECOSYSTEM RECEIVED A BOOST WHEN THE UNIVERSITY OF BRITISH COLUMBIA (UBC) OKANAGAN CAMPUS launched the Innovation UBC Hub in the Innovation Centre in Kelowna, B.C., joining forces with Accelerate Okanagan and cementing the region's position as the Silicon Valley of the North (with cheaper housing and shorter commutes).

"We're solving problems that affect each and every one of us," says Camille Saltman, who is director of entrepreneurship for UBC Okanagan and based in the new UBC Hub. "What makes this generation of students special is that they see a problem and rather than shrugging their shoulders, they're creating social impact ventures – they're creating solutions, in effect, to make the world into the place where we all want to live."

These solutions not only benefit society but create a huge economic windfall for the region, the province and the entrepreneurs alike. An economic impact study commissioned by Accelerate Okanagan and the Central Okanagan Economic Development Commission and released mid-September revealed 15 per cent growth in the technology sector year over year for the past six years – making Kelowna the fastest-growing tech and innovation hub in the country. There are currently 693 high-tech companies in the Okanagan region, employing 12,500 people and creating an economic impact of $1.67-billion, a 30 per cent growth since the last economic study was completed in 2016.

"There's something going on. I've never, ever seen growth like this," says Raghwa Gopal, CEO of Accelerate Okanagan, who points out that 55 per cent of the employees working in tech jobs are under 35. "Among everyone working here, rolling up our sleeves to make new things, there's this bubbling civic pride – a shared desire to change lives in our community is helping fuel this momentum."

"A rising tide lifts all boats," is the phrase Ms. Saltman uses to explain the growth in her community. The Innovation Centre brings together people with disparate interests – AI and medicine, interior design and vegan food, cancer research and nanotechnology – collaborating and with the help of Accelerate Okanagan bringing new products from ideation to market with a collaborative thrust.

"The economic impact of a robust cluster of innovation companies on a community is profound," says Ms. Saltman, adding that the imprint left by Lane Merrifield, co-founder of Club Penguin, benefactor of the hub and a new "dragon" on CBC's Dragons' Den, encourages participants to shoot for the moon. "To see so many diverse solutions and so much passion from the mentors and the innovators is energizing and we've only just started – everyone's shared desires are to build and to grow."

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>
> **Raghwa Gopal**
> CEO of Accelerate Okanagan

Collaborations between different institutions and among people working in diverse fields at the Innovation Centre in Kelowna, B.C., are taking new products from ideation to the market. SUPPLIED

Indeed, goals for Accelerate Okanagan and the Innovation UBC Hub are ambitious. Mr. Gopal is content, temporarily, with the $1.67-billion economic impact and likes the rate of growth in the Okanagan. However, he believes this region can double that number – and double it soon.

"Two years ago, we said that if we build this dream of technology and innovation, we could make a $5-billion impact," says Mr. Gopal, proudly. "We're happy with our growth, but we're not there yet. And we have the people, of this I am absolutely certain, to manifest this innovation dream."

PROFILE

INDECIPHERABLE FROM THE REAL THING

Avalon Holographics, headquartered in St. John's, collaborates with nanofabrication facilities at both the University of Waterloo and the University of Alberta to create and test nano-sized devices for holographic display technologies. The devices will ultimately produce a life-like display that is "nearly indecipherable from the real thing," says the company's president, Wally Haas.

In the past, holograms have relied on a system of mirrors to manipulate light and create a 3D effect, explains Greg Holloway, a researcher at Waterloo's Quantum NanoFab facility. But a much higher fidelity 3D projection can be created using nano-sized structures on the scale of the wavelength of light. The structures cause the light to bend, yielding a 3D projection.

They are essentially tiny pillars mounted on glass that Dr. Holloway sculpts into the desired shape using electron-beam lithography, which uses a high-energy beam of electrons to burn away material. The resulting device is 100 microns in size, barely visible.

Nine of the company's 40 employees also work on developing holographic devices at the nanoFAB Fabrication & Characterization Centre at U of A, which is the country's largest clean room open to industry use.

Mr. Haas says these research facilities are indispensable to his company's success – the precision of the electron-beam lithography equipment at Waterloo, for example, allows Avalon to advance its technologies further than they otherwise could. And about the U of A facility, he says, "Without it, we'd shut down. We are lucky to have access to its size and capability."

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PRIMED FOR PARTNERSHIPS

Research Facilities Navigator boosts collaborations, amplifies research infrastructure's impact

Sharing infrastructure, resources and research findings are priorities for the Ocean Frontier Institute, where collaborations are valued for their potential to create a bigger impact. **SUPPLIED**

IN LABRADOR, A MULTI-DISCIPLINARY TEAM OF RESEARCHERS IS WORKING CLOSELY WITH INUIT COMMUNITIES. Their aim is to translate knowledge about past and current ecosystem indicators – from microbes to fish to plants to humans – into a comprehensive strategy for effectively managing coastal areas that face climate change, fishing challenges and other pressures.

"At the end of the day, we will be judged on whether our research has a demonstrable impact," says Wendy Watson-Wright, CEO of the Ocean Frontier Institute (OFI), an interdisciplinary and transnational hub for ocean research led by Dalhousie University, Memorial University of Newfoundland and the University of Prince Edward Island. "We have two objectives: to better understand how and why the ocean is changing, and to use research to identify potential solutions."

Approaches to ocean development need to be sustainable, globally competitive and benefit communities – and these goals can only be achieved through team efforts, says Dr. Watson-Wright. OFI is working with a range of partners from communities, industry and government as well as researchers from Ireland, Norway, Germany, France and the U.S.

More than 500 international research teams work on seabed mapping, ocean observation, weather, climate and polar research, marine biotechnology and marine spatial planning in the Atlantic Ocean. Dr. Watson-Wright sees two important factors that allow Canadian researchers to fully participate – and take leadership roles – in such research efforts: one, existing research infrastructure, and two, a culture of collaboration.

Both components have been advanced through the efforts of the Canada Foundation for Innovation (CFI), which was founded just over 20 years ago to establish state-of-the-art research facilities in universities and colleges across Canada to help curb the "brain drain," says Roseann O'Reilly Runte, the CFI's president and CEO.

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>
> **Wendy Watson-Wright**
> CEO, Ocean Frontier Institute

> **We succeeded in creating many wonderful facilities that help to keep bright minds in Canada and also attract researchers from around the world.**
>
> **Roseann O'Reilly Runte**
> President and CEO, Canada Foundation for Innovation

"The remarkable results of these investments have been magnified by collaborations among government, universities, businesses and industry," says Dr. Runte, who adds that the networks created have significantly shaped Canada's research and innovation landscape.

"We succeeded in creating many wonderful facilities that help to keep bright minds in Canada and also attract researchers from around the world," she says. "We are now also looking at amplifying our impact by focusing our outreach on connecting the private sector to these experts and their facilities."

One key initiative the CFI has launched to facilitate this outreach is the Research Facilities Navigator, an online directory of cutting-edge labs and expertise that was initially comprised of CFI-funded infrastructure but is now being expanded to include a range of other facilities, says Dr. Runte.

Mona Nemer, Canada's chief science advisor, says the federal government is currently exploring the potential of adding National Research Council labs to the Navigator in order to make the database even more comprehensive.

"The Navigator currently lists the major infrastructure available in academic settings, including universities, teaching hospitals and colleges. We will be adding the major infrastructure that exists in federal labs to that list," says Dr. Nemer. "This opens the possibility for all researchers to share the equipment that is essentially funded by taxpayers' money. It also provides small and medium-sized enterprises – and sometimes even large companies – access to the infrastructure and expertise they need for their research and development objectives."

Expanding the directory can also "enhance the lines of communication between intramural and extramural science," says Dr. Nemer. "It will allow us to use infrastructure more efficiently. For example, we know what equipment is available in academic labs, but some of the same instruments may also exist in federal labs. So, if one goes down or is oversubscribed, another could be used.

"This will create additional opportunities for collaboration among researchers in various sectors, including government, the private sector and universities," she adds.

An example where pooled resources have enhanced collaborations is the Southern Ontario Network for Advanced Manufacturing Innovation (SONAMI), says Marc Nantel, associate vice-president, research and innovation at Niagara College.

"Colleges and institutes across the country are known for their applied research capacity. They play an essential role in helping small and medium-size enterprises, which make up about 95 per cent of the Canadian economy, meet their research and development goals or overcome challenges," he says. "When companies come to us and explain what they need, [Niagara College] may have the right tools and expertise to find a solution or we may collaborate with another facility."

The idea behind SONAMI is to give industry access to a complete range of advanced manufacturing tools and expertise available in seven institutions: Niagara College, Sheridan College, Mohawk College, McMaster University, Conestoga College, Fanshawe College and Lambton College.

All seven labs have specialized infrastructure and capabilities, and where one facility can't succeed alone, another can step in, explains Dr. Nantel. For a project with the Grimo Nut Nursery, for example, Niagara College designed, built and tested a prototype of equipment for cracking a special type of nut, the heartnut, and McMaster University is working on the manufacturability of the unit – all in a bid to enhance the competitiveness of a local family farm.

The ability to access a whole suite of facilities in all areas of application across the country serves to strengthen existing links and encourage new ones – and the numbers of connections facilitated through the Navigator speak for themselves, says Dr. Runte. "Over the past six months, we have observed growing engagement from visitors to the Navigator site," she says. "We have also been highlighting the Navigator in trade delegations around the world."

The Navigator now consistently sees an average of 2,000 visits to its site per month, with one-fourth to one-third of that traffic originating from international sources, in particular, the U.S., the U.K. and India. For Dr. Runte, this shows that Canadian research infrastructure is a magnet for local, regional, national and international partners alike.

Sharing infrastructure, resources and research findings is essential in areas like ocean research, believes Dr. Watson-Wright. "For example, we are relying on government and private partners to spend time on their vessels, and our international partners have also offered us access to their ships," she says. "And we are happy to share data from our extensive in-water infrastructure, which includes buoys, floats, wave gliders and profiling gliders."

Collaborative efforts simply have the potential of achieving a greater impact, says Dr. Watson-Wright. "Together, we are working on solutions that benefit the economy, the environment and ultimately society."

NO BARRIERS TO PARTICIPATION

Advancing accessibility in all areas of society

THE CONCEPTS OF DIVERSITY AND INCLUSION NEED TO BE MORE THAN SLOGANS OR ADD-ONS, and they need to be embedded into every level and area of our society. The research of Adrian Chan, professor in the department of Systems and Computer Engineering at Carleton University and director of the Research and Education in Accessibility, Design, and Innovation (READi) program, is advancing a basic civic right that has been woefully under-represented: accessibility.

Dr. Chan believes physical and virtual spaces, such as residences, offices and websites, as well as products, services and information have to be designed to suit the disparate needs of our entire society – not just the able-bodied but the huge segment of our population with visible and non-visible disabilities. His work in adaptive technologies has been recognized all over the world.

"Everyone is beginning to recognize the big need in accessibility, but the education element was always absent," says Dr. Chan, comparing accessibility scholarship to 'environmental sustainability', which was a small niche topic but is now pervasive, and like 'accessibility' encompasses many different levels of education. "That these discussions are now multidisciplinary is a big inroad because one discipline can't solve all of the accessibility problems. However, we're starting to all pull together right now: we're on the precipice of a big moment of change."

The moment was solidified and then bolstered when Dr. Chan won a CREATE grant from the Natural Sciences and Engineering Research Council of Canada worth $1.65-million over six years. In addition to the much-needed funds, the grant, awarded in May 2017, also brought recognition to Dr. Chan's research and development. His philosophy espouses design solutions imparted at the beginning of a project, as opposed to retrofitted, and encompasses physical as well as mental health issues, including autism and Asperger syndrome. Dr. Chan believes that in a just society, the playing field should be even for everyone. This human rights issue gives meaning to his work and his life.

Carleton University professor Adrian Chan (pictured left, with student) is working to advance accessibility and inclusion through the Research and Education in Accessibility, Design, and Innovation (READi) training program. SUPPLIED

> **From social work to music and art, history to engineering, accessibility is being addressed from all perspectives and it's exciting.**
>
> **Dr. Adrian Chan**
> Professor in the department of Systems and Computer Engineering at Carleton University

"Engineering attracted me because it's the problem-solving profession, but one thing we often forget is that it's also a service profession and should be to the benefit of society," says Dr. Chan, who started his career as a computer and biomedical engineer and landed on accessibility later, as he resonated with the cause. "From social work to music and art, history to engineering, accessibility is being addressed from all perspectives and it's exciting. I feel fortunate to contribute in my own small way."

Contributions in accessibility have manifested from the grassroots disability community, where the slogan "nothing about us without us" is brought to every project and considered in every aspect of Dr. Chan's work. And while universities from Carleton to Queen's to the University of Ottawa update their curriculums to incorporate accessibility design, simultaneously large corporate entities are adding previously unseen positions, like a chief accessibility officer at Microsoft. In a world in which a significant portion of society is affected by a disability, accessibility isn't only timely and just – it's good for business and it's good for society at large.

Dr. Chan, a father of four, hopes to make the world a better place for future generations. "The problems are complex and require new, multidisciplinary thinking to move the needle forward to develop solutions, but I see it happening and I feel the change," says Dr. Chan. "If we're going to move accessibility forward, then we have to develop the next generation of leaders. I believe that our biggest success will be found in the students who finish their program and change the world in their careers."

PROFILE

THIRD-GENERATION PLAYGROUNDS

After designing and manufacturing jungle gyms and other outdoor children's play spaces since the early 1990s, Active Playground Equipment Inc., a family-owned Ontario playground equipment company, decided to expand its market into adult and outdoor fitness equipment.

In order to add components like rubber grips and electronic device holders that make it easier for grownups to incorporate the equipment into fitness programs, the company turned to Lambton College's Centre for Industrial Material Development for help. In addition, new coating was needed to protect the equipment's features from harsh winters.

At Lambton College, Shahram Karimi and his team investigated protective coating materials to determine the optimal composition and thickness. Using corrosion chambers, high temperature and pressure autoclaves and lab equipment that generates a high voltage helped to speed up deterioration and corrosion rates that would take months under normal outdoor conditions. "Collaborating with small businesses like this one is invaluable to how colleges can contribute to developing new technologies," says Dr. Karimi. "The company benefits from finding answers to their challenges, and we benefit from the chance to demonstrate the value of our knowledge, and to learn from the work."

By using high-powered lab equipment, the researchers determine how well materials hold up – which will then allow the company to make informed decisions on the design of their new playground equipment.

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LESS STRESS FOR REFEREES

Better support for sports officials includes training with innovative technology

WE'VE ALL BEEN THERE: AT THE EDGE OF OUR SEATS AND ENGROSSED IN A GAME WHEN THE REFEREE'S WHISTLE INTERRUPTS THE ACTION. What comes next could be greeted with cheers or groans, depending on whether the call is in favour of our team or the opposition.

"Any call an official makes typically pleases half the people," says Kim Dorsch, a professor in the University of Regina's Faculty of Kinesiology and Health Studies. "I was watching a [football] game last night and sure enough, people got riled up when the official didn't call a penalty – and this non-call led to a touchdown.

"Too often, officials are made scapegoats if the outcome isn't the one we want. But we have to realize that referees have to make very complex cognitive decisions in short periods of time," she says. "And generally, they don't have opportunities to practise some of the mental skills needed to make these calls."

Dr. Dorsch, whose research in the field of sport psychology examines the psychological stressors and coping styles of sports officials, has found that enhanced training can lead to better outcomes for hockey officials.

"Attrition rates are high in most sports, and the loss of qualified officials can have significant financial implications," she says. "Hockey Canada, for example, is losing about one-third of its officials."

The first step toward alleviating what Dr. Dorsch calls a "crisis in officiating" is understanding the types of stress referees commonly face. "There are two main categories of competition stressors – one is the fear of making mistakes and the other is the fear of abuse, which could be verbal or even physical abuse coming from players, coaches or spectators," she explains.

Other stressors can come from working with an officiating team or from being employed by an organization, says Dr. Dorsch. "Last year, for example, a hockey official made a controversial call and was subsequently suspended by the organization – this perceived lack of support can create additional stress."

All these elements can impact the performance of officials, and they can also lead to resignations. Dr. Dorsch has found that referees encounter different stressors as they move through the various levels of officiating.

"The fear of making mistakes is perceived as the greatest stress factor, even greater than the fear of abuse, especially for referees who are just starting out – it causes officials from many sports to retire," she says.

Training, however, has proven to be helpful in addressing this particular stressor, Dr. Dorsch says. "Generally, education and training programs for officials focus on rules and communication only – they don't include cognitive skills training. The only training referees typically receive is during an actual game, when a lot is on the line."

In partnership with the Saskatchewan Hockey Association, Dr. Dorsch's team worked with hockey referees to evaluate the use of NeuroTracker, an innovation developed in Montreal, which aims to enhance mental performance by challenging users to track multiple targets moving dynamically in 3D space.

"We had a group of officials go through NeuroTracker training sessions designed to enhance the brain's attention, executive function, working memory and processing speed – things that were once thought of as not trainable," she says. "We then brought in hockey supervisors to evaluate their officiating performance and compare it to a control group without knowing who had been training with the device."

The performance of officials exposed to NeuroTracker sessions was noticeably better, says Dr. Dorsch. "Referees need a wide peripheral awareness. Training devices that hone referees' abilities to track multiple objects can enable them to see things better on the ice," she says. "It's like doing squats for the brain."

By proving that more can be done to prepare officials for their challenging role, Dr. Dorsch's research has broad implications, not just for hockey but most competitive sports.

Compared to professional athletes and coaches, referees typically have a low profile. They simply don't receive the same attention, support or compensation from sports organizations, and Dr. Dorsch aims to shift that balance.

"Qualified officials are essential to the game," she stresses. "We need to improve outcomes and retention rates for referees by doing more research and offering better tools and training opportunities."

University of Regina researcher Kim Dorsch is working with hockey referees to achieve better outcomes through mental performance training. SUPPLIED

CRACKING THE GENOME CODE

Crop scientists advance scientific methods and food security

WHEAT IS THE WORLD'S MOST CULTIVATED CROP, SUPPLYING 20 PER CENT OF ALL CALORIES CONSUMED THROUGHOUT THE WORLD – MORE THAN ANY OTHER FOOD SOURCE. It's estimated that to meet the future demands of a projected world population of 9.6 billion by 2050, wheat productivity needs to increase by 1.6 per cent each year.

A research team led by the University of Saskatchewan (U of S) has played a key role in an international discovery that will have an impact on the food security of millions of people around the world – the sequencing of the billion-piece jigsaw puzzle that is the bread wheat genome.

It's a discovery that's expected to bring disruptive innovation to wheat improvement, paving the way for wheat varieties that are better adapted to climate challenges, along with higher yields, disease and pest resistance, and enhanced nutritional quality.

"This breakthrough research means we have a comprehensive blueprint of the wheat genome that will significantly improve the tools breeders have to produce new and better varieties over the long term," says Curtis Pozniak, researcher and wheat breeder at the U of S Crop Development Centre in the College of Agriculture and Bioresources.

For the past 13 years, more than 200 scientists in 20 countries have been endeavouring, through the International Wheat Genome Sequencing Consortium, to complete the genome sequence for bread wheat and make publicly available the new genomic assembly for breeders.

Kirby Nilsen, a recent U of S PhD graduate and now an assistant plant breeder at the U of S Crop Development Centre, is among the first researchers worldwide to use the blueprint to develop pest-resistant wheat crops. He used the genome sequence to identify genes responsible for solid wheat stems, which act as a barrier to sawfly damage. SUPPLIED

COMPUTING TECHNOLOGY ENABLES SPEEDIER GENOME SEQUENCING

Last August, the journal Science published the highest-quality genome sequence ever produced for the bread wheat variety Chinese Spring.

Dr. Pozniak led Canada's contribution to the wheat genome initiative through the Canadian Triticum Applied Genomics (CTAG2) project, which also includes scientists from the National Research Council, Agriculture and Agri-Food Canada, the University of Guelph and the University of Regina.

"Essentially we have completed the genome jigsaw puzzle with all the pieces put together in their correct positions and order, providing an enormous advantage in time and effort for breeders when searching for genes that control important traits in the crop," says Dr. Pozniak. "What once took years to do can now be done in a matter of weeks."

This had long been considered an almost impossible task. The wheat genome is five times larger than the human genome and more complex, with most of the genome composed of identical repeated elements. Picture a billion-piece jigsaw puzzle, with the added challenge that 90 per cent of the pieces look essentially the same – such as blue sky with a sprinkling of clouds.

Originally, consortium scientists were laboriously mapping wheat's 21 chromosomes chromosome by chromosome. That's when Dr. Pozniak and CTAG2 co-lead Andrew Sharpe came up with the idea of using cutting-edge computing technology for speedier genome sequencing. They had previously worked with Israeli company NRGene which had developed new DNA assembly software programs.

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> Researcher and wheat breeder at the U of S Crop Development Centre in the College of Agriculture and Bioresources

"The chromosome-by-chromosome approach would have worked, but it's very, very time-consuming," says Dr. Pozniak.

Within three months, the team had a framework sequence for the entire genome. Combining that with already generated data enabled researchers to identify the precise location of 107,891 genes and more than four million molecular markers, as well as how and when the genes are expressed.

"This is the full, uninterrupted genome sequence rather than the fractured picture available previously," says Dr. Sharpe, director of genomics and bioinformatics at the U of S Global Institute for Food Security (GIFS).

"This resource will have immediate application in the wheat breeding program at the U of S Crop Development Centre where we will see the impact over the next few years," he adds.

LEADING LARGE-SCALE INITIATIVE ON GLOBAL FOOD SECURITY

Maurice Moloney, executive director of GIFS at the U of S, said this discovery will have a major impact on global food security.

"In light of climate change, water shortages and limitations on the availability of arable land, we will need to rely on plant genetics to increase wheat productivity," says Dr. Moloney. "Solving the massive puzzle of the wheat genome will go a long way towards accomplishing that, similar to the growth that was made in maize and rice crops after their genomes were assembled."

The U of S team now leads a larger-scale international initiative to sequence more than 10 cultivated wheat varieties from the main growing areas across the globe. Led by Dr. Pozniak, the 10+ Wheat Genomes Project began last year and uses the same NRGene technology to sequence these genomes, with several varieties already complete.

"To understand what genes do in wheat plants, you need multiple sequences so you can start comparing variants to see what makes them unique. You can then associate these differences with important traits that we select in breeding programs," says Dr. Pozniak. "By the fall of next year, we expect a complete catalogue of variations and an understanding of how those impact a crop in the field."

In Canada, wheat accounts for more than $4.5-billion in annual sales and, when value-added processing is factored in, contributes more than $11-billion each year to the Canadian economy.

U of S vice-president Research Karen Chad says the discovery highlights the importance of international research collaboration, noting researchers at IPK Gatersleben in Germany, Kansas State University in the U.S., Tel Aviv University in Israel, and Illumina Inc. were involved.

"No single researcher, university or country can solve global challenges like global food security," she says. "Working together with our international partners and funding agencies, the complex set of genetic instructions encoded in wheat DNA are now known and breeders will soon have the tools they need for transformative crop innovations."

The CTAG2 project is funded by Genome Canada, Genome Prairie, Western Grains Research Foundation, and the Saskatchewan Ministry of Agriculture, as well as the Saskatchewan Wheat Development Commission, the Alberta Wheat Commission, and the Canada First Research Excellence Fund through the "Designing Crops for Global Food Security" initiative at the U of S.

AFFIRMING COMMITMENT TO INDIGENOUS LEADERSHIP AND KNOWLEDGE

Indigenous futurity – referring to future generations or future states or conditions – is a key aspirational area at York University. This acknowledges the power of research that embraces future potential and past reality as integral to sound, contemporary work.

"In a time when truth, reconciliation and justice are dominating public discourse about Indigenous issues and when Indigenous communities in Canada and around the world are facing severe health, social, legal and societal challenges, the need for research that imagines the future has never been greater," says Robert Haché, vice-president Research & Innovation, York University. "Drawing on Indigenous ways of knowing, ways of being, worldviews and laws, futurities research will contribute to changing lives and will significantly affect nations, communities and individuals."

As a recognized global leader in socially engaged research and knowledge mobilization, York is committed to building community partnerships in research, and pledges to facilitate research that is relevant to Indigenous life and respects Indigenous approaches to knowledge and learning, says Dr. Haché, adding that the university also affirms a commitment to respectful, relevant, Indigenous-formed and led research, scholarship and related creative activity.

A young role model for First Nations women, Autumn Peltier, represented her community at a knowledge-sharing symposium, part of York's Indigenous Environmental Justice Project. SUPPLIED

"York's researchers are ideally positioned to collaborate with Indigenous communities on research that will contribute to improving community life while enhancing cultural, economic and environmental sustainability," he explains. "Never losing sight of history, this research opportunity simultaneously insists on consideration of our relationships to Indigenous futures and the ways they will continue to influence and shift the emphasis in current research and innovation."

York is home to a large group of scholars, both Indigenous and non-Indigenous, whose research exists in relation to Indigeneity. Recent Indigenous research initiatives include the artistic productions and creations that explore Indigenous relationships with Canada; the role of youth in health promotion; the interactions between Indigenous and non-Indigenous laws; the histories of Métis, First Nation, Inuit and Native-American relationships with colonialism; and Indigenous language policies, art and education.

"Indigenous-related research consistently references community. An Indigenous worldview insists that having good relations with all of creation is foundational to healthy communities," says Dr. Haché. "Notions of relationship-building, reciprocity of process and outcome, respectful engagement with each other and relevance of the work to those involved in the projects are integral to the research. This opportunity encompasses post-colonial interests, trans-Indigenous theory and other forward-looking research."

In the coming years, the focus of this research will include social, cultural, artistic and justice areas. Collaboration in exploring Indigenous and non-Indigenous approaches in these areas, while understanding the need for Indigenous researchers to take the lead, will mark the distinctiveness of York's approach, he adds. "The intent is to ensure that Indigenous-related research includes a commitment to listening to and learning from Indigenous peoples' knowledge, laws, ecology, spiritual practices and experiences."

PROFILE

HIGH-IMPACT PROTEINS THROUGH PLANT-BREEDING, PROCESSING INNOVATION

Plant protein is playing an increasingly important role in food security – and is expected to make up around one-third of the world's protein market by 2050.

This trend, driven by global population growth as well as health and environmental concerns, is motivating the work of Protein Industries Canada (PIC), a supercluster of partners working to position Canada as the leading centre for high-quality plant-based protein, says Bill Greuel, CEO of PIC.

A key area of investigation focuses on value-added processing efficiency. "Let's take yellow peas, for example," says Mr. Greuel. "There is a huge market globally for pea protein as a functional ingredient and energy source in a number of different foods and animal feed products."

Food processors are looking for processing methodologies that are energy- and water-use efficient and also yield products with a high protein concentration, he says. And industry- and research partnerships can provide valuable answers. Existing research infrastructure, such as the Food Processing Development Centre in Alberta, for example, already has a track record of helping companies develop new food products using ingredients coming from the region.

PIC is supported by the federal government's Innovation Superclusters Initiative, which Mr. Greuel sees as a response to the urgent call to boost Canadian research and innovation intensity. "The supercluster initiative allows industry to select key projects – and the government provides funding to de-risk private sector investments," he says. "Since the intention is to focus on projects with the greatest economic impact, partnering with industry is essential. Industries know cost structures, technical constraints and customer needs – they know what it takes to achieve the highest return on investment."

PIC's objective is to look at all aspects of food production, says Mr. Greuel. In the example of the yellow peas, genome analysis and advanced breeding techniques can potentially achieve an increase in the peas' protein concentration already at the breeding stage.

"This can make processing much more efficient and allow processors to reach new markets with products that have a higher protein content," he says. "We aim to invest in research and development along the entire supply chain – from plant breeding, farming and processing all the way to the end user."

UNDERSTANDING ASTHMA

Exploring the factors driving the rise of chronic diseases

OVER THE LAST DECADES, ALLERGIC DISEASES HAVE INCREASED TO EPIDEMIC PROPORTIONS in Canada. Asthma, for example, has seen rising numbers since the 1970s, with currently 3.8 million people over the age of one living with asthma. What are the factors driving this increase? And how does our genetic makeup interact with the numerous environmental factors that play a role in the development of chronic diseases?

These are some of the questions Dr. Allan Becker, professor and head of the Section of Allergy and Clinical Immunology in the Department of Pediatrics and Child Health at the University of Manitoba, is working to illuminate.

"We believe that chronic diseases are driven by gene-environment interactions," he says. "It's now apparent that chronic non-communicable diseases, such as asthma and allergies, diabetes and inflammatory bowel disease, are increasing broadly. The reason asthma and allergies have figured prominently among them is because they are the earliest to develop – in childhood."

An internationally recognized leader in pediatric allergy and asthma research, care and education, Dr. Becker is especially interested in understanding what is happening in early life and how outcomes for families at risk can be improved.

"Our mission encompasses understanding the importance of early life events, preventing the development of allergies and asthma and helping children and families manage the disease," says Dr. Becker. "We know you can't pick your parents, but you can influence your environment to a certain degree – and we are learning more and more about the factors that can play a role in the development of chronic disease."

For asthma and allergies, there is a wide spectrum of factors to consider, from common inhaled allergens, such as dust mites or pollens, to foods or other environmental exposures such as tobacco smoke or traffic-related air pollution. Exposure to chemicals, which could be anything from non-stick cookware to volatile organic compounds, can also play a role along with other health determinants like stress, says Dr. Becker. "We have to consider how stress and other psychosocial aspects shape how our immune system functions and influence whether our genes are expressed or not."

Allan Becker, a scientist at the University of Manitoba and the Children's Hospital Research Institute of Manitoba, has followed several cohorts of children to investigate what drives the development of allergies and asthma. SUPPLIED

> **We believe that chronic diseases are driven by gene-environment interactions.**
>
> **Dr. Allan Becker**
> Professor and head of the Section of Allergy and Clinical Immunology in the Department of Pediatrics and Child Health at the University of Manitoba

Such complexity requires multidisciplinary collaboration, he says. "As a clinician scientist, I've been fortunate to help bring together researchers from different fields to work toward a common goal." Dr. Becker adds that research needs support at every level: from clinicians and scientists to institutions and funding agencies.

The aim is to translate research into tools for health-care professionals and children and families, says Dr. Becker. As a founding member of the Canadian Network for Asthma Care, he led the development of an asthma educator education program, AsthmaTrec (now known as RespTrec), which is used across Canada, and was lead author of the first Canadian Pediatric Asthma Guidelines.

"I'm also involved in the Science Committee of the Global Initiative for Asthma, which provides a strategy for guideline development for countries around the world," he adds.

Dr. Becker is the recipient of the 2018 Dr. John M. Bowman Winnipeg Memorial Rh Institute Foundation Award. "I am enormously grateful for the recognition that comes with the award, and I am especially delighted because I had the opportunity as a medical student and pediatric trainee to work with Dr. Bowman," says Dr. Becker. "He was an impressive individual, and much of what he taught me has shaped what I do."

The message Dr. Becker wants to convey to Canadians is that children with asthma and allergies can live normal, active lives, which can include a full range of physical activities. "We have made great strides in understanding how asthma and allergies can be managed on a day-to-day basis," he says. "And we continue to undertake research to prevent the development of allergies and asthma and look for cures."

PROFILE

LEARNING VIA CELLPHONE

Innovation involves creating new or improved goods and services that have value for consumers, firms, markets and society at large.

"Innovation can also help us fulfill our sense of responsibility to the world, by creating access to basic health care, education and decent jobs, and creating the conditions where people can survive and thrive, regardless of where they are born," says Prateek Awasthi, director of policy, advocacy and community, Engineers Without Borders (EWB) Canada.

Advanced technologies are already being applied for social good, with astounding results, he says. An example of a venture EWB supports is M-Shule, an adaptive, mobile learning management platform that uses machine learning to create personalized learning plans and exercises for primary school students in Kenya on a basic cellphone.

"This improves the quality of education and creates better learning opportunities for students, particularly those who need it most," says Mr. Awasthi. "What the world probably needs as much as our peacekeepers and our aid dollars, is our talent and technology. That's where our innovation programs can make a difference."

CHICKEN FEATHERS

ANCIENT MANUSCRI

OUT-OF-BO EXPERIEN

Truth is rarely simple, and what was true yesterday may not be true tomorrow. Our researchers seek the truth, wherever it may lead...

IPTS...

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HIGH-IMPACT COLLABORATIONS

How to create net-positive communities

BY 2050, TWO-THIRDS OF THE GLOBAL POPULATION WILL LIVE IN URBAN AREAS. Experts have long called for reducing the negative environmental impact of cities, but Walter Merida believes this is not enough.

"I am convinced we have the technologies and knowledge to ensure urban systems go beyond having a zero impact – toward achieving a net positive impact on the planet and on society," says the associate dean, Research and Industrial Partnerships, UBC's Faculty of Applied Science and director, Clean Energy Research Centre.

Dr. Merida is not only talking about a community's environmental performance: he also envisions benefits for the economy and the health and well-being of all inhabitants.

Such panoptic vision can only be advanced through the collective effort of multiple stakeholders and experts from a broad range of disciplines. At UBC's Faculty of Applied Science, for example, three schools "become the perfect interface for creating comprehensive solutions – the School of Architecture and Landscape Architecture (SALA), the School of Nursing, and the School of Community and Regional Planning (SCARP)," says Dr. Merida.

Ron Kellett, director of SALA, agrees that an interdisciplinary approach provides better answers to the question of what makes communities healthy, vibrant and inclusive. "While public policy initiatives still contain goals such as improving energy efficiency, water quality and carbon resilience, these agendas have become part of a larger objective – to make communities better places to live for everyone," he says.

How, then, can communities be designed for eight-year-olds and 80-year-olds alike? The parameters for different age groups are not that different, insists Prof. Kellett. "When we design places where essential services are within walking distance and linked by pathways, then the likelihood of the services being used and people connecting is much higher."

> **"I am convinced we have the technologies and knowledge to ensure urban systems go beyond having a zero impact – toward achieving a net positive impact on the planet and on society.**
>
> **Walter Merida**
> Associate dean, Research and Industrial Partnerships, UBC's Faculty of Applied Science and director, Clean Energy Research Centre

At a time when the number of Canadian seniors is increasing, investigations into the factors determining their health and well-being are crucial not only for improving outcomes for older individuals but for the health of our communities and society, says Elizabeth Saewyc, director of the School of Nursing.

"Nurses are concerned about issues such as walkability, because we know that if seniors aren't staying active, they lose muscle mass and balance, which can lead to falls and fractures, and these can affect their ability to live independently," she says.

Technology may help improve the quality of life for seniors. Smart homes and the Internet of Things, for example, offer opportunities for health monitoring and achieving a timely response to health events, says Dr. Saewyc. Targeted tools, such as virtual reality software to help manage chronic pain, or video messages from family members to comfort people living with Alzheimer's, are promising new interventions.

"But we also need to ensure that nurses and other health-care providers are not distracted by gadgets and data," she cautions. "We have to engage with technologies in ways that are ethical and ensure that people's humanity and needs remain central to the care we provide."

In cities, technologies only achieve the desired impact when the whole system is functional, says Prof. Kellett, who compares a community to an organism. "You need to get the basic structure – the bones – of the place coherent, before you add the other components, like the muscles and circulation system, to make it work together."

Prof. Kellett's team leverages planning and urban design expertise to model the impact of different policy or technology interventions. "In our laboratory, we create simulations that merge numbers and pictures to show how a transportation system would work, what a corridor of larger buildings and services would look like, and how different measures would affect performance metrics and livability metrics," he says.

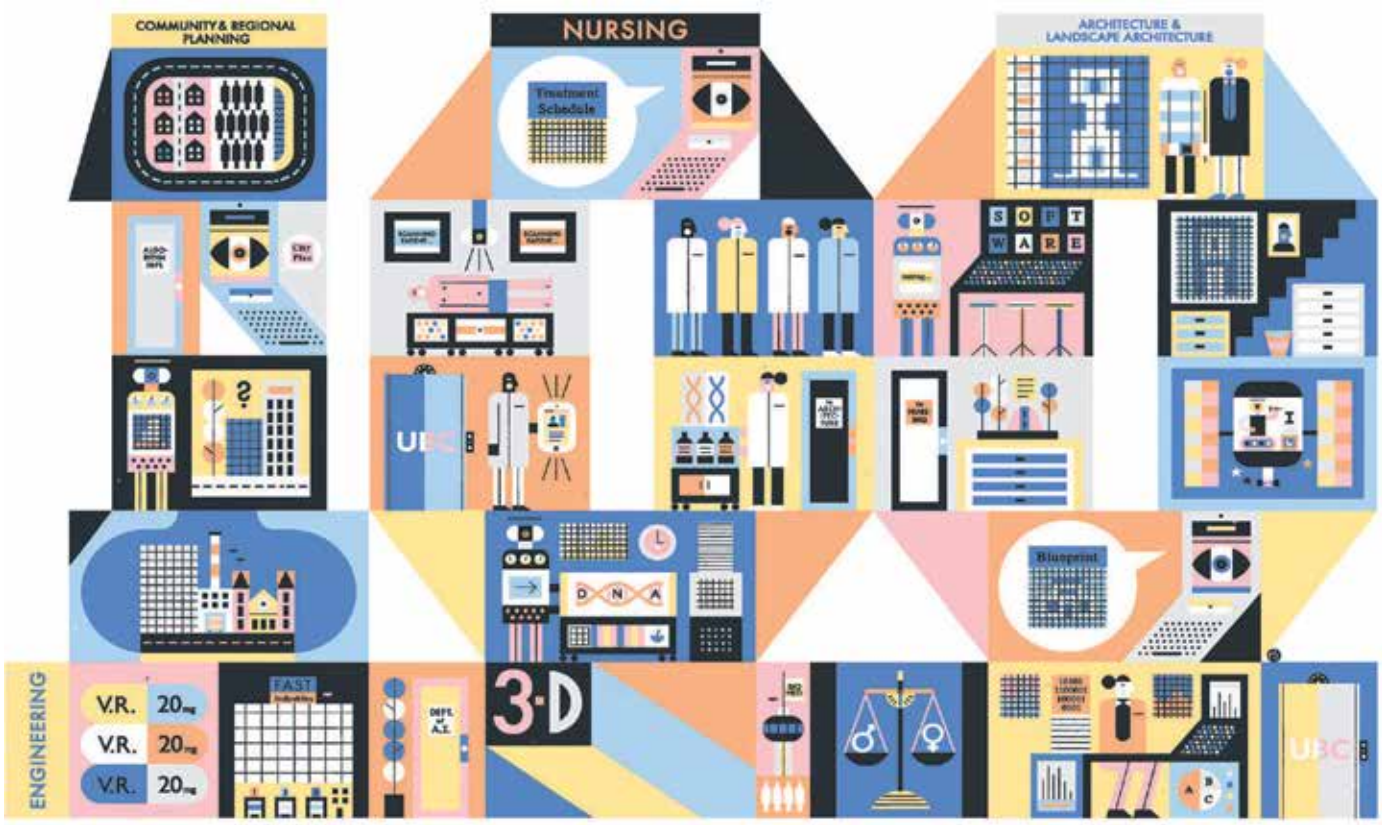
Heather Campbell, director of SCARP, believes it is vital to consider technology and policy in tandem. There are a number of emerging technologies that are shaping communities, for example, car- and ride-sharing methodology and autonomous vehicles, or systems that make buildings healthier and more energy-efficient – but all technological advances need to be accompanied by an appropriate regulatory framework, she explains.

"Smart cities may be the ones having all the technology on board, but really smart cities will effectively integrate and manage the technologies to ensure they deliver the maximum potential," says Dr. Campbell. "That's where UBC's Faculty of Applied Science has a huge advantage: it brings together the people with the technical know-how and the people who can establish which technologies benefit a community as a whole and how to make sure no segment of the population is excluded."

Engaging all key stakeholders from the outset to determine which technology solutions best meet specific societal needs can deliver even stronger results, says Dr. Campbell. "Rather than sit in separate silos, it makes sense to join efforts between health, engineering, planning and architecture, because we all live in places that integrate all those things.

"And since we don't have infinite resources, it's important to maximize the potential of all projects," she adds.

"One of the things we have learned from working in clean energy is that advancing one aspect cannot come at a cost to another," says Dr. Merida. He suggests that considering a range of diverse perspectives allows us to determine how research and innovation can best serve community interests, so we can focus on technology and policy interventions that advance the common goal of achieving net benefits across all areas of society.



If we are looking to advance benefits for all of society and the planet over the next 100 years, we have to engage multiple stakeholders and experts from a broad range of disciplines. The Faculty of Applied Science at UBC can serve as a model through its integration of expertise from community planning, nursing, architecture and landscape architecture, and engineering for the development of comprehensive solutions. **SUPPLIED**

PROFILE

SUSTAINABLE OCEAN DEVELOPMENT

Ocean research is informing innovative solutions that benefit both the economy and the environment. Examples are technologies that turn fish waste into valuable byproducts, such as fish oil or collagen supplements, and new fisheries tools that efficiently harvests scallops with less impact to the sea floor.

These are some of the tangible benefits resulting from inquiries into how and why the ocean is changing – and how research can identify effective approaches to ocean development, says Wendy Watson-Wright, CEO of the Ocean Frontier Institute (OFI), an interdisciplinary and transnational ocean research hub situated in geographic proximity to the Northwest Atlantic, the most intense sink for carbon on the planet.

Over the past 200 years, the ocean's net uptake of carbon dioxide is equivalent to 42 to 44 per cent of emissions associated with human activity. Eight to 10 per cent of that amount has been sequestered within the Northwest Atlantic, due to an "overturning circulation," where northward-flowing near-surface waters reach the Labrador Sea and areas east of Greenland. There, the surface water becomes dense and sinks to a considerable depth, from where a deep cold current transports these waters far into the ocean's interior.

Dr. Watson-Wright says, "The ocean's ability to absorb carbon dioxide has far-reaching consequences for the global climate – it also has important social and economic implications."

In addition to working with international teams of researchers to assess and monitor the effectiveness of the ocean's carbon sink, OFI brings together collaborations dedicated to translating knowledge into solutions in a number of areas, including fisheries, aquaculture, security and technology, she adds.

INNOVATION SAVES COSTS, MINIMIZES DISRUPTIONS

Aging infrastructure is one of the biggest challenges facing municipalities across Canada. Lack of funds in most jurisdictions means some essential services are stretched to breaking point.

For example, the average age of Canada's potable water pipes is 37 years, according to the current Canadian Infrastructure Report Card. In some municipalities, cast iron pipes were laid up to a century ago and are now badly corroded and leaking.

Digging up pipes to replace or refurbish them, which can be expensive and disruptive, is no longer the only solution thanks to the development by the Quebec firm Sanexen Environmental Services. Its innovative Aqua-Pipe technology allows pipes to be refurbished in place without having to be dug up.

Sanexen, a subsidiary of Montreal's Logistec Corporation, owns 51 per cent of Toronto-based FER-PAL Infrastructure, which specializes in trenchless water pipe refurbishment for municipalities in Canada and the United States using Sanexen's Aqua-Pipe product. FER-PAL CEO Shaun McKaigue says municipalities are increasingly looking for cost-effective ways to extend the life of water pipes and reduce the disruption caused when roads are dug up to access the damaged infrastructure.

FER-PAL Infrastructure uses innovative technology called Aqua-Pipe, which allows pipes to be refurbished in place without having to be dug up. **SUPPLIED**

The technology FER-PAL uses – called cured-in-place pipe (CIPP) – involves the excavation of just one hole to get to the pipe, which is cleaned of rust and other debris and then lined with Aqua-Pipe, which is made up of tubular polyester jackets with the inner jacket bonded onto a polyurethane elastomer.

Apart from overall cost savings and reduced disruption, the trenchless process benefits the environment by avoiding the much larger carbon footprint that would result from cut-and-cover excavation and increased traffic congestion due to road closures.

"Trenchless technology such as CIPP for water main rehabilitation can reduce the carbon footprint by 80 to 90 per cent," says Mr. McKaigue. "It also prevents future water main breaks and the loss of potable water that has cost money to treat. So that's another environmental benefit as well as a cost saving."

Achieving acceptance of the technology among municipalities once it was developed involved finding champions, he adds.

"Specifically, municipalities like Hamilton, Toronto and London were early adopters. They could see the long-term benefits through cost savings, less disruption and reduced environmental impact," says Mr. McKaigue. The technology is now widely used in Canada and the U.S. FER-PAL's goal is to expand its market further across Canada and deeper into the U.S.

While winning support from municipalities is important, Mr. McKaigue says the company strives to maintain good relationships with the communities where pipe rehabilitation is carried out. "In a way, our customers are the taxpayers who live in the municipalities where we work, and we understand that customer service is important," he says. "The technology helps reduce disruption, but we still need to make sure that communities are fully informed about what we are doing and why, and when we do that the general reaction is, 'wow, what a great idea.'"

But Mr. McKaigue believes an equally important wow factor is that Aqua-Pipe is a Canadian success story made possible by Logistec's long-term view of business and its willingness to invest in research and development. "In typical Canadian fashion, we tend to not blow our horn," he says. "But this is a great story. Aqua-Pipe was invented in Canada, it's manufactured in Canada, we are world leaders in the technology and now we are exporting it to the U.S. and, in time, the rest of the world."

CHAMPIONING INCLUSION

Using technology to ensure everyone is engaged

FROM THE INTERNET AND CLOUD COMPUTING TO ROBOTICS AND ARTIFICIAL INTELLIGENCE, technology over the last two decades has evolved and transformed into increasingly sophisticated innovations.

For Deborah Fels, director of the Inclusive Media and Design Centre at Ryerson University in Toronto, one thing has stayed constant through the years: her belief in using technology to break barriers for people whose disabilities often keep them from engaging more fully in their communities.

"I'm an engineer who believes in the power of innovative technology to serve people with disabilities," says Dr. Fels, a professor at Ryerson's Ted Rogers School of Information Technology Management. "That's the point of inclusive design."

Dr. Fels' work has helped a diverse range of users – from kids who were missing school because they were often in hospital to creative artists who are blind or have low vision, deaf or hard of hearing. For example, her PEBBLES robot – which helped more than 30 Canadian kids go to school via videoconference from their hospital beds – was later commercialized and evolved into the "WebChair" and used by more than 400 students in Europe.

PEBBLES also evolved into the Emoti-chair – a "vibrotactile" technology that uses low-intensity vibrations to convey sounds to people who are hard of hearing. The Emoti-chair features eight channels of 16 speakers that run alongside the user's spine.

"We were asked by the deaf community to provide better access to sound than what captioning provides, which basically tries to describe or name sounds," explains Dr. Fels. "We found that low-intensity vibration added a lot to the missing soundtrack."

The Emoti-chair led to the development of WebMoti, which connects children with autism spectrum disorder to their classroom.

"People with autism have overloaded senses, which is why a lot of them have so much trouble in classrooms and noisy environments," says Dr. Fels. "What WebMoti does is allow students to study outside the classroom while maintaining a remote presence in class. Students can control what stimulation they're getting by turning off video but maintaining audio or by adding low-intensity vibration."

Ryerson professor Deborah Fels' innovations have helped a diverse range of users – from kids who were missing school because they were often in hospital to creative artists who are blind or have low vision, deaf or hard of hearing. MARK BLINCH

> **We found that low-intensity vibration added a lot to the missing soundtrack.**
>
> **Dr. Deborah Fels**
> Director of the Inclusive Media and Design Centre at Ryerson University

This innovation has opened the door to a new, vibrotactile art form, which now has its own creation space, the VibraFusion Lab in London, Ont. Together with hard-of-hearing new media artist David Bobier, Dr. Fels co-founded the VibraFusion Lab four years ago as a development lab, educational centre and presentation space for vibrotactile expression.

Close to 40 Canadian and international artists have performed and led workshops at the lab, whose model has been replicated in Toronto, the Dominican Republic and London, U.K.

With the pervasiveness of the Internet as a mode for sharing information, Dr. Fels identified a need to create sign language websites without using written text. The resulting innovation is SignLinkStudio, created specifically for designers of websites for the deaf community.

"Deaf people have a visual culture – they sign to communicate, while written language is all about sounds and not much to do with visuals," she says.

Instead of content and links in text, SignLinkStudio uses videos to communicate information. Like most of Dr. Fels' work, this innovation led to another: a kiosk where people can make short videos of their experiences in activities such as shopping or dining – much like Yelp or Google reviews but with video.

"So now we have something that's more accessible to a deaf audience," says Dr. Fels, noting that this innovation subsequently led to a technology that allows patients to share their stories with health-care providers through short videos.

More than two decades after she took the reins at the Inclusive Media and Design Centre, Dr. Fels continues to find new ways to use technology to ensure everyone is engaged in this age of information. She recently started a program called Lab Elders, where retired scientists, engineers and other technology experts work with Ryerson students and give them guidance on their projects.

"It's a great way for retired older adults to get involved and use their expertise to contribute to the next wave of innovation," she says.

READY FOR AI

York plays vital role in integrating artificial intelligence into society

FROM SMARTPHONES THAT ORDER OUR MORNING COFFEE to the remote calibration of computers in the outer reaches of our galaxy, artificial intelligence (AI) pervades almost every aspect of our lives. York University, a comprehensive research-intensive institution, plays a vital role in the integration of AI into society.

"York is at the forefront in visual perception technologies, space exploration, robotics and manufacturing technologies, remote sensing, intelligent information systems and cognitive analytics," says Robert Haché, vice-president, Research & Innovation, York University. "We are building on our unique niche alongside global intellectual leaders in the humanities, social sciences, health and law, who are laying new ground expounding the moral, ethical and legal implications of AI adoption."

Today's rapid evolution of technologies is often referred to as "the fourth industrial revolution." At its heart is the development of independent decision-making capacity, or AI, that frees devices and sensors from dependence on human decision-making, explains Dr. Haché. "AI involves capacities ranging from visual and auditory perception, reading skill, the ability for accurate autonomous decision-making based on existing pre-acquired information, and the ability to continuously improve function as additional data and experience are acquired."

AI has been predicted to be the most disruptive technology ever invented – a technology that, when fully adapted, will fundamentally transform our economic, social, legal and cultural environments,

> **"In the coming years, York researchers will become leading intellectual voices in articulating how AI will affect culture, living, economics and identity.**
>
> **Robert Haché**
> Vice-president, Research & Innovation, York University

York University is leading the development of visual perception technologies, working through the Vision: Science to Applications (VISTA) program to provide global leadership in research focusing on the intersection of computational and biological vision. SUPPLIED

he says. "With York's focus on equity, social justice and business and technological development, and its interdisciplinary approach to research spanning the scientific to the philosophical, our researchers are positioned to make a unique contribution to AI. They can also ensure AI's equitable and moral adoption to maximize its benefits, while minimizing unintended consequences."

York is leading the development of visual perception technologies, working through the Vision: Science to Applications (VISTA) program to provide global leadership in research, focusing on the intersection of computational and biological vision. The university is also the international leader in using 3D printing to develop autonomous technology for cleaning space debris, space robotics and space manufacturing. Other researchers are working at the cutting edge of autonomous robotics, remote sensing, localization, intelligent information systems and cognitive analytics.

"On the human side, scholars from across the humanities, social sciences, health and law are studying the moral, ethical and legal implications of AI adoption," says Dr. Haché "They are looking into the effects on governments, labour markets, the legal system, personal and national security, human health and health systems. They are studying AI's challenges to our sense of individual identity and collective humanity.

"In the coming years, York researchers will become leading intellectual voices in articulating how AI will affect culture, living, economics and identity. Our work will guide the adoption of AI in a manner that counters the prevalent tendencies of increasing disparities between rich and poor, haves and have nots, working to improve the human condition."

As a home to a proud tradition of scholarship and the pursuit of discovery and innovation, York's commitment to excellence brings together a rich diversity of perspectives with a strong sense of social responsibility that is making a difference to the world around us, he adds.

HOW TO TRANSLATE REAL-WORLD DATA INTO BETTER HEALTH OUTCOMES

How can electronic population health information be translated into effective tools for education and decision-making with the power to improve the outcome for individual patients?

Data related to osteoporosis, a condition that causes bones to become thin and porous, for example, can be used to predict the risk of an individual suffering a hip fracture, suggests Lisa Lix, an internationally-recognized expert in methods for research and surveillance of chronic health conditions and Canada Research Chair in Methods for Electronic Health Data Quality. Her collaborations on osteoporosis-related fracture risk assessment tools have helped to develop clinical guidelines on fracture prevention and treatment.

Living in a country where a wealth of current and historic health data is available and deemed a valuable resource for research, Canadians are at an advantage, believes Dr. Lix, a University of Manitoba biostatistician and population health scientist and professor in Community Health Sciences, Rady Faculty of Health Sciences. "Having access to data for looking at population health issues is key – but we also need to have confidence in the data," she says. "My research focuses on data quality and on building this confidence in using data for a multitude of purposes that can lead to better health outcomes."

Dr. Lix primarily works with real-world data – population-based data – coming from three sources: administrative health data (i.e., transactional data generated in the health care system), electronic medical records, and clinical or health-care registries, such as the Joint Replacement Registry for the Winnipeg health region.

Data from these sources are used in anonymized form for research, says Dr. Lix. "We systematically look at trends in chronic diseases, which can enable us to create prediction models to better understand health risks and outcomes."

University of Manitoba researcher Lisa Lix (pictured left) helps to transform electronic health-care data into tools for achieving better health outcomes. SUPPLIED

Large population-based databases allow researchers to analyze the distribution of disease over time, across geography, across age groups, for males and females, as well as for small segments of the population, she explains. And a significant volume of historical data can help us understand generational changes.

"In Manitoba, for example, real-world data go back to the 1970s. Being able to look at long-term trends can help us gain a perspective of how chronic diseases are changing over time," says Dr. Lix. "Some of my research looks at changes in the health histories between different generations, such as comparing the health of offspring and parent at the population level."

Dr. Lix's research to accurately measure the prevalence and incidence of conditions like diabetes and arthritis, for example, is used by the Public Health Agency of Canada's Canadian Chronic Disease Surveillance System, a collaborative network of provincial and territorial surveillance systems enhancing the scope of data on 20 chronic diseases.

The aim is to support the planning of health resources and development of health policies and programs. Health information can also aid advocacy groups like Osteoporosis Canada in their mission to increase education and public awareness, which, in turn, can help patients.

"Building prediction tools is all about outcomes for patients – that's the value of looking at differences in the burden of chronic disease in different populations," says Dr. Lix. "This information can influence a person's decision about seeking care or modifying behaviour that may reduce a particular risk."

Canada's expertise in working with real-world health data is also informing practices worldwide, she adds. "We've developed innovative methods for evaluating the quality of data – and these methods are shared internationally to assist governments, agencies and researchers in building confidence in the results coming from research using real-world data."

Clearly, it is experts like Dr. Lix, with experience in the statistical methods required for working with complex health-care databases and addressing the challenges of error-prone data, who contribute to Canada's advanced position in this field.

PIXEL PERFECT

From the challenge of the next game to potential applications in particle physics, biomechanics, medical imaging and more

THE TINIEST DETAIL – an oddly drawn plume of smoke or teeth with an unnatural tint – can yank video game players or animated movie audiences out of their states of suspended disbelief.

Such disruptions could soon be things of the past, thanks to a new Industrial Research Chair in the Faculty of Engineering at McGill University in Montreal.

The Natural Sciences and Engineering Research Council (NSERC) of Canada teamed up recently with Montreal-based Ubisoft Entertainment and McGill to create the NSERC/Ubisoft Industrial Research Chair in Believable Virtual Character Experiences. The chair was awarded to associate professor Derek Nowrouzezahrai, director of McGill's Graphics and Imaging Lab.

"In animation and video games, you can simulate to an accuracy of 99.9 per cent, where every strand of hair or article of clothing is rendered meticulously," explains Dr. Nowrouzezahrai. "But humans are so hardwired for spotting that 0.1 per cent that isn't quite right, so the big challenge we're tackling in this research chair is how to get 3D renderings 100 per cent correct so that your characters are more believable and authentic."

Supported by equal funding of $750,000 each from NSERC and Ubisoft, as well as in-kind contributions from McGill and Ubisoft, the $2.5-million research chair brings together some of the brightest minds in video game design, production and software engineering.

Over the chair's five-year mandate, about 20 undergraduate, graduate and postdoctoral students from McGill's Faculty of Engineering will work with a select team at Ubisoft's La Forge applied research lab to develop techniques that will enhance the credibility of virtual worlds.

"McGill students will have access to Ubisoft's full range of resources – from our game engines and data to the expertise of our technologists," says Yves Jacquier, executive director, production studio services at Ubisoft Montreal. "By the same token, Ubisoft team members who come into the lab will have the opportunity to focus on his or her research instead of always being pitched into production to solve the challenge of the next game."

Yves Jacquier (left) and Derek Nowrouzezahrai (right) pictured with members of the McGill Graphics and Imaging Lab on location at Ubisoft, Montreal. OLIVIER BLOUIN

Creating credible virtual worlds with authentic, believable characters goes far beyond accurate rendering and surface texture representations, says Mr. Jacquier. The physics of this simulated world – including the reflection of light and the movement of hair, clothing and other objects – need to align with the physics of the real world.

Solving this challenge has implications beyond video games and animation, says Dr. Nowrouzezahrai. As McGill and Ubisoft tackle longstanding computer graphics problems, they'll be generating complex mathematical models with potential applications in particle physics, biomechanics, computational statistics, biology, medical imaging, robotics and artificial intelligence.

"Let's say we develop a new, biologically motivated technique for synthesizing computer-generated images of skin; such a technique may also be adapted to detect melanoma given the model's knowledge of how light interacts with skin," explains Dr. Nowrouzezahrai. "Similarly, medical imaging with technologies like MRIs rely on the same type of physics we use to simulate lighting in virtual worlds, and the better we develop these models the more we can synthesize data to help doctors better diagnose illnesses."

Sylvain Coulombe, associate vice-principal, Innovation and Partnerships at McGill, cites the NSERC/Ubisoft Research Chair as yet another great example of strategic public-private partnerships that expand the university's innovation portfolio and diversify its connections to Quebec and Canadian industry.

"It's a bi-directional exchange between our two organizations," he says. "Ubisoft has brought us a challenge that requires a lot of research and that will involve a lot of our well-trained students, and our students get exposure and training in an industry-leading company."

What's also notable about the NSERC/Ubisoft Research Chair is Ubisoft's commitment to sharing the results of the research. Members of Ubisoft and Dr. Nowrouzezahrai's research teams will submit academic works for publication throughout the course of the program.

"One goal is to provide the broader scientific community access to our techniques, which they could reproduce and extend for their own applications," he says. "Ubisoft fully supports this, which I think is just amazing for students at McGill and for the scientific community."

PROFILE

DATA LITERACY

How can client-facing companies – from the retail and restaurant industries to travel companies – arrive at a better understanding of their customers? And how can the vast amounts of data that companies store for marketing and security purposes help to advance their business objectives? These are the questions that are at the core of the collaborative approach of Theory and Practice (TAP), says Rogayeh Tabrizi, TAP's co-founder and chief science officer.

"We see a real gap between organizations' desire to implement data-driven strategies and an actual utilization of data driving actionable and effective insights that could inform these strategies," she says.

Dr. Tabrizi has brought together a team with such diverse backgrounds as data science, economics and physics to tackle the challenge of helping partner organizations use data more efficiently and design intelligent models that point to business levers that generate lasting outcomes.

"Customers reveal their preferences in non-trivial ways and using data to identify and quantify these individuals' wants and needs goes beyond writing predictive models," she says. "Understanding, choosing and defining variables that are fed into AI, machine-learning and deep learning models are as important as the models themselves – if not more."

Dr. Tabrizi believes it is "essential that organizations understand the value of storing customer data, how such new knowledge should be used, and how to improve existing methods for getting a maximum impact from this data."

EXCELLENCE IN TRANSPLANTATION

From discovery to impact: how U of A research has saved the lives of millions

TRANSPLANT SURGEON-RESEARCHERS AND PHYSICIAN-SCIENTISTS AT THE UNIVERSITY OF ALBERTA have conducted ground-breaking research in transplantation that has improved the quality of life of millions of people and saved countless lives. But their best work may be yet to come.

CHANGING THE FUTURE FOR PEOPLE WITH DIABETES

James Shapiro is best known as the primary creator of the Edmonton Protocol, a life-saving procedure introduced in 2000 for those with a dangerous subset of type 1 diabetes. But he has never stopped innovating, and his most life-changing work may be underway right now.

In 1998, when he became director of the University of Alberta's islet transplant program, he implemented a new multi-pronged approach – "making seven or eight changes all at once to try to make something work" – with his colleagues, which led to the Edmonton Protocol.

"I learned from my patients what a terrible disease diabetes really is for many of them," says Dr. Shapiro. The Edmonton Protocol resulted in the first patient being able to go off insulin altogether, a result that was then replicated in seven more patients. The findings were presented at the American Transplant Congress, setting off an unprecedented response, with media and patient families calling from all over the world.

Successful islet transplantation means better blood sugar control, a higher quality of life and reduced risk of complications. "One of the very early patients has now been free of the need for insulin injections for almost 20 years, with his original transplant. Just over 60 per cent of patients continue to have measurable function," reports Dr. Shapiro.

But – in addition to the longer-term function failure of transplanted islets – there simply aren't enough donors. "Last year, there were 31,812 organ donors worldwide – there were 422 million people living with diabetes. If this treatment went mainstream, it would take us 90,000 years to treat everybody," he explains.

The gap led Dr. Shapiro's quest to find an alternative solution through stem cell research. "We've treated around 20 patients in Edmonton so far, and there've been several more treated in different centres across the U.S. in two different trials. What we've found is we can get the cells to survive, differentiate and turn into human insulin-inducing cells," he says, adding that he and his team are also collaborating with scientists across Canada to find a way to enable patients to generate islet cells using their own stem cells.

What will this mean for people with diabetes? In an interview with folio.ca, Kerry Elliott, the first patient to undergo a stem cell transplant as part of the clinical trial in Edmonton, put it this way: "Diabetes is doing its best every day to kill you, and you are doing your best to stop it from doing that. To be free of that, to not have to worry about that – even for a week – I couldn't even tell you what that would be like. It would be unbelievable."

TWENTY-TWO YEARS LATER, A PATIENT WRITES TO SAY 'THANK YOU FOR MY LIFE'

Lori West trained as an MD, a pediatrician and a pediatric surgeon before going to Oxford University to train in medical research. "You can't dabble around if you hope to change the field," she says, adding that her motivation was compelling. "I worked with children who had lethal heart problems. If something didn't change, they were going to die."

She started by taking on one of the most daunting obstacles to her patients' survival – the accepted notion that organs can only be transplanted between two people of the same blood type. She was convinced this didn't apply to her infant patient population, but it meant turning an accepted clinical practice "on its head," she explains. "It took a while to convince people that the science was sound."

The first child who had one of the cross-blood-type transplants is now 22 years old. "He is healthy. He has a future. He wrote to me a few years ago on Valentine's Day, the anniversary of his transplant, to say, 'Thank you for my life,'" she reports.

Yet there are always more problems to tackle. One she's focused on now is the anti-rejection drugs transplant patients must take for the rest of their lives to prevent their bodies from rejecting their organs. "They can have many side effects; they don't always work. So, transplant researchers and clinicians are always asking how we can do better."

Among the University of Alberta researchers who have made significant scientific contributions to the university's transplant program are James Shapiro (top image, with team), Darren Freed and Jayan Nagendran (pictured above), Philip Halloran and Lori West. TOP, SUPPLIED; BOTTOM, LAUGHING DOG PHOTOGRAPHY

> **We have to find better ways of looking after people than we have right now. To make that happen, we must believe in the process of discovery.**
>
> **Dr. Philip Halloran**
> Nephrologist and researcher

> **I worked with children who had lethal heart problems. If something didn't change, they were going to die.**
>
> **Lori West**
> Medical researcher

As scientific understanding of the body's immune system advanced over the last decade, Dr. West and her team began investigating the possibility of harnessing regulatory cells called Tregs to suppress rejection with fewer side effects.

Her national work also involves increasing donation rates. "Because we don't have enough organs, we can't even try with all the people who could potentially benefit," she says. "I just met with the family of someone who died many years ago; it was so important to them to have something good come out of that tragedy. They want us to understand that it means the world to them, even all these years later, that someone is still alive because their son's heart was transplanted."

HELPING DONATED ORGANS WORK LONGER

"I can say categorically, without bias, that (Philip) Halloran is the most influential individual in transplantation over the past 25 years," said Bruce Kaplan, professor of medicine at the Mayo Clinic in Scottsdale, Ariz.

Dr. Halloran's work in researching the immune response to organ transplants has contributed to a dramatic drop in the rate of transplantation failures over the past 30 years, from 55 to five per cent.

A nephrologist and researcher, he has investigated the mechanisms of organ transplant rejection and injury and treatments that improve outcomes in transplantation and organ diseases. He developed the world's leading centre for molecular studies of organ transplants and organ diseases, and recently developed the Molecular Microscope Diagnostic System (MMDx), which reads organ transplant biopsies using microarrays.

"When you first start seeing patients and think some of their problems can be solved, you think, 'Who is going to solve them? Well, maybe I can help,'" says Halloran. "When I was in medical school, I met a kid on the ward who was my age, 22 or 23, and dying of kidney failure. It stays on your mind – you go through your career thinking that you could have saved his life, about how you can help develop solutions for people who are suffering."

While his profession applauds his accomplishments, Dr. Halloran's focus is fully on the future. "The goal for us is using the revolution in genetics to help make people better, to change care. We have to find better ways of looking after people than we have right now. To make that happen, we must believe in the process of discovery."

CARING FOR ORGANS OUTSIDE OF THE BODY

The University of Alberta has been a cardiac surgery leader and innovator since Canada's first open-heart operation was carried out in Edmonton in the 1950s. Its latest global breakthrough is ex-vivo organ support system (EVOSS) technology, capable of solving two of the greatest challenges in health care: the few healthy donor organs available and the brief window of time now available for transport.

Developed by surgeon-scientists Darren Freed and Jayan Nagendran, the first EVOSS is a portable device that replicates the way breathing moves the chest cavity, ensuring a constant supply of blood and oxygen to the donor organ in transport. A vast improvement on the ice chests that have been used for the past 30 years, EVOSS prevents transport damage and even gives surgeons the opportunity to fix damaged organs before transplanting them.

Dr. Nagendran grew up "down the street" from the University of Alberta, where he trained as a doctor and surgeon. After studying at Stanford University, he returned to Edmonton with the aim of establishing a translational cardiac surgery lab. Five years ago, he was joined by Cambridge-trained Dr. Freed. "As a heart surgeon, you see it so directly – we need to do better, and we can do better. One in three of our patients waiting for lung transplants die before they get an organ," says Dr. Nagendran.

EVOSS was first used in 2014; in October, Dr. Nagendran completed the first lung transplantation using lungs that would have otherwise been considered non-viable.

The team is now at work on a heart device, and the perfusion techniques they've developed are being used with livers, kidneys and, most recently, limbs. They are now commercializing the technology in order to make it available to patients worldwide.

The transplant program at the University of Alberta serves over six-million square kilometres, making it the world's most geographically isolated transplant program. But the vision of its research team is larger still.

"An organ that becomes available here may be a perfect match for somebody in the Netherlands, and vice versa – but it won't happen unless we're able to keep these organs safe for longer periods of time," says Dr. Nagendran.

TIMELINE

UNIVERSITY OF ALBERTA'S TRANSPLANT FIRSTS

1962: Lionel McLeod develops the first chronic hemodialysis program in Canada,

1967: William Lakey performs the first cadaveric kidney transplant.

1982: The Islet Transplantation Group is founded, with Ray Rajotte as director.

1985: Dennis Modry does the first heart transplant in Western Canada and the first heart-lung transplant in the region (in 1986).

1989: The first liver transplant is performed by Norman Kneteman.

1989: The diabetes research team reports its first successful combination islet cell and kidney transplantation in patients with end-stage diabetic kidney disease.

1990: A six-year-old patient received the first pediatric liver transplant; the first infant liver transplant follows in 1994.

1998: James Shapiro and Kneteman perform the first emergency living-related donor liver transplant in Canada on two-year-old Bradley whose life is saved when he receives part of his dad's liver.

1999: Shapiro performs the first whole pancreas transplant in Alberta.

2000: The first "domino" transplant in Alberta is performed; a type of surgery done when a donor liver causes damage to the other organs of the recipient; the liver is then transplanted to a more stable patient.

2000: Edmonton Protocol in islet transplantation is published in the New England Journal of Medicine. The publication showed that the Edmonton Protocol increased islet transplant success rates from eight to 100 per cent at the one-year mark. In 2001, clinical trials begin around the world.

2001: The American Journal of Transplantation is launched in Edmonton. Founded and edited by Philip Halloran, it has become the most successful and highly cited journal in the field.

2001: The first living donor lung transplant in Western Canada (the third in Canada) takes place.

2003: Dave Bigam performs the first intestinal transplants in Western Canada.

2004: The first infant heart transplant immediately after birth is performed.

2008: The 1,000th liver transplant at the University of Alberta Hospital is performed.

2011: Pediatric cardiologist and clinician-scientist Lori West is instrumental in the creation of the Alberta Transplant Institute (ATI).

2013: The Canadian National Transplant Research Program, a unique national collaboration, is formed and housed in the ATI. Lori West becomes its founding director.

2015: Surgeons perfuse a donated liver out of the body, which keeps the liver preserved as if it is still in the body before transplantation.

2016: Philip Halloran wins the 2016 Prix Galien research award for his work in reducing transplant failure rates from 55 to five per cent.

MARKET READY

Industry and college partnerships reach research and development objectives

Niagara College (NC) works closely with industry partners, like Hamill Machine, where owner and CEO Bob Benner (right) credits the partnership for his company's ability to expand into new markets, while doubling his machine shop and workforce. Pictured with a recent project success, the microgreens harvester dryer, are Lucas Howe, mechanical engineering student and research assistant with NC's Research & Innovation division (left) and James Dahl, NC mechanical engineering graduate and now Hamill lead engineer. SUPPLIED

PRESSURE SORES ARE A MAJOR CAUSE OF CONCERN, especially for people experiencing impaired sensation and prolonged immobility. When OKE Polymer Systems, a Canadian manufacturer specializing in therapeutic support surfaces and medical, occupational and recreational applications, decided to pursue the development of a product that offers people the ability to sit longer without discomfort, the company sought a partner with specific applied research capabilities: Niagara College.

"Colleges and institutes have the equipment and expertise that is reflective of the needs of industry in their region," says Marc Nantel, associate vice-president, research and innovation, Niagara College. "By doing applied research, we help companies create new products and services, which then can generate new jobs and wealth."

> **"By having state-of-the-art infrastructure that reflects the market, we not only service our industry partners, we also give students the skills they need to succeed in those industries.**
>
> **Marc Nantel**
> Associate vice-president, research and innovation, Niagara College

In order to serve companies like OKE Polymer Systems even better, Dr. Nantel was instrumental in establishing the Southern Ontario Network for Advanced Manufacturing Innovation (SONAMI), which includes facilities at Niagara College, Sheridan College, Mohawk College, McMaster University, Conestoga College, Fanshawe College and Lambton College.

"This is a very collaborative effort. Our principal investigators regularly compare notes and discuss what type of equipment we need for different projects," says Dr. Nantel. "We are also working closely with an industry advisory committee that provides strategic input about what companies are looking for."

OKE Polymer Systems, for example, turned to Niagara College because its parent company Blake Medical reported a very positive experience of working with Mohawk College, says Dr. Nantel. He adds that this initiative required the use of 3D scanning, design and printing technologies – to focus on developing a proof-of-concept tooling mold to integrate into OKE Polymer Systems' manufacturing line for trial runs.

The result? Another successful SONAMI project that resulted in a dressing that relieves pressure to the tailbone. Traditional products for this purpose, which are typically made of foam, are limited because they are unable to fully form to the shape of the body – and this is something the new gel can achieve.

"By having state-of-the-art infrastructure that reflects the market, we not only service our industry partners, we also give students the skills they need to succeed in those industries," he says. "And we help to create solutions that address very specific societal needs."

PROFILE

GAME-CHANGERS IN SHIPBUILDING TECHNOLOGY

Irving Shipbuilding has invested $750,000 in the University of New Brunswick's Marine Additive Manufacturing Centre of Excellence as part of its value proposition commitments under the National Shipbuilding Strategy – Canada's 30-year plan to renew the fleets of the Royal Canadian Navy and the Canadian Coast Guard.

"Irving Shipbuilding, which is developing the next generation of Canadian surface-vessel competence, tends to be a leader in new technology adaptation," says Dr. Mohsen Mohammadi, the centre's director of research and development, "It understands that if you want to make the best ship, you have to have the best technology, and the Marine Additive Manufacturing Centre of Excellence is providing that technology."

Irving Shipbuilding president Kevin McCoy stated when the company's commitment was announced that the centre's new technology was a potential game-changer. "Initiatives like the Marine Additive Manufacturing Centre of Excellence have the potential to change and advance the face of shipbuilding and other sectors in Canada," he says. "Our value proposition commitments allow us to invest in game-changers like this one and help achieve the National Shipbuilding Strategy's goal of creating a sustainable and vibrant Canadian marine industry."

In 2011, Irving Shipbuilding was selected by the Canadian government to build the Royal Canadian Navy's new combat fleet, a program that comprises 21 vessels and $25-billion over a period of 30 years. It is currently building six Harry DeWolf-class Arctic offshore patrol ships for the Canadian federal government. The ships are designed to operate in first-year ice of 120-centimetre thickness, allowing the Royal Canadian Navy to have unescorted access to areas of the Arctic that were previously inaccessible.

Q&A

GAINING ESSENTIAL SKILLS FOR THE NEXT DECADE

Q&A WITH DENISE AMYOT, PRESIDENT AND CEO OF COLLEGES AND INSTITUTES CANADA

What are the essential skills that students need for succeeding within the next decade?
The challenge for today's students is that to be successful in such a rapidly evolving environment, they can never stop learning. This means that as educators, we must equip them with the tools to be lifelong learners. In this context, having a strong foundation in your discipline is essential, but soft skills are also more important than ever as graduates need to be resilient and adaptable. Promoting entrepreneurial values can also be very useful as graduates will increasingly have to manage their own careers, which might take all kinds of unexpected turns.

How can educational institutions best foster research, innovation and entrepreneurship skills?
Providing hands-on experiences remains one of the best ways to foster skills and competencies, which is why it is at the heart of the college and institute model. Our members try to include some form of work-integrated learning opportunities in all their programs, including by encouraging students to take part in applied research projects or entrepreneurial activity.

How can the impact of research infrastructure be maximized through collaboration?
Partnerships are definitely the key to maximizing the impact of research infrastructure. Colleges and institutes need to have access to the latest technologies in order to train graduates that will be ready for the current and future requirements in their fields. Meanwhile, businesses – and in particular SMEs or startups – often have a hard time accessing the equipment and expertise they need to fully develop an innovative idea or concept. Sharing those resources through research partnerships is a win-win situation that helps fuel innovation while providing valuable learning opportunities for students.

However, creating these linkages takes work, which is why our association is calling for more research support funding for applied research projects in order to secure and amplify the long-term impact of college and institute applied research offices in the innovation ecosystem.

> **Partnerships are definitely the key to maximizing the impact of research infrastructure. Colleges and institutes need to have access to the latest technologies in order to train graduates that will be ready for the current and future requirements in their fields.**

What are examples of research partnerships advancing new and innovative solutions?
Last year alone, our members were involved in over 7,300 research partnerships, so there are almost too many examples to choose from. We are also very proud to see them contribute to almost all sectors imaginable, from digital technologies and advanced manufacturing to social innovation. Whether it's the Nova Scotia Community College helping develop the next generation of biofuel using microalgae, or SAIT Polytechnic developing a safe drug-delivery system to administer a new life-saving asthma treatment, there is no doubt that the innovation happening at colleges and institutes has positive implications for all Canadians.

How are colleges and institutes prepared to keep up with rapid societal changes?
Colleges and institutes have always striven to be nimble institutions and are continuously looking to update their programs to reflect the needs of both students and employers. In fact, all programs are developed with input from a program advisory committee, which includes industry experts and local employers.

This consultation process is ongoing and allows colleges and institutes to review all their programs on a regular basis. It also helps faculty stay on top of all the latest shifts and trends in their field. This makes colleges and institutes particularly adaptable and puts them in an enviable position when dealing with disruption. The pace of change might have increased, but for them, it's nothing entirely new.

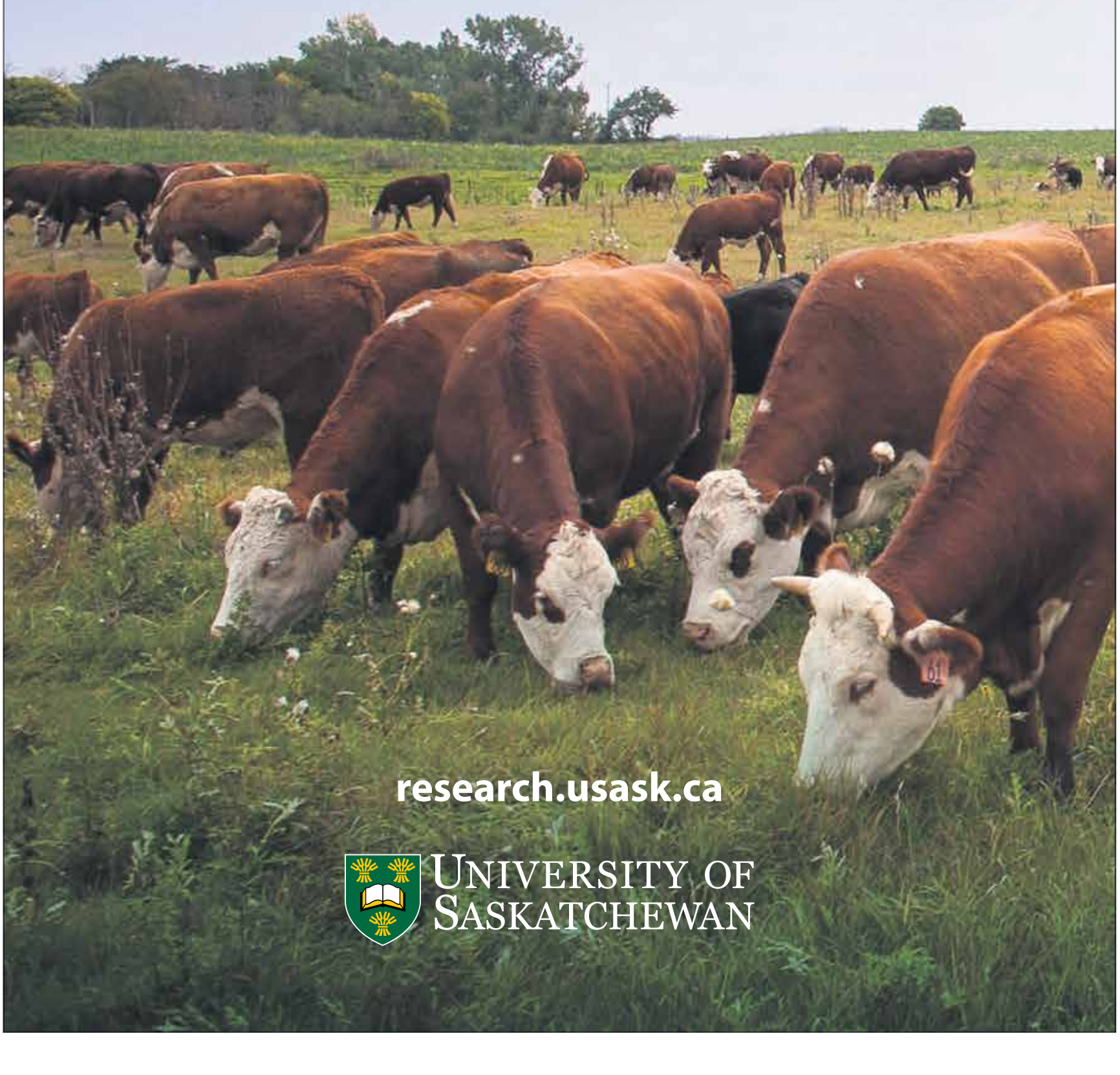
INNOVATION FEEDS THE WORLD

By 2050, food production must more than double to keep pace with the world's growing population. To do this, the world needs new methods, policies and technologies that cross a wide variety of disciplines and industries.

At the University of Saskatchewan, we're taking the lead on tackling this pressing global issue by building on our long and successful track record in agriculture, food sciences, animal health and environmental research.

- Our newest research centre, the Livestock and Forage Centre of Excellence, is the largest and most comprehensive of its kind in Canada. It will enhance animal welfare and human nutrition, and will lessen environmental impact.
- The Global Institute for Food Security is home to one of USask's two Canada First Research Excellence Fund programs, and drives innovation in agricultural practices in both the developed and developing world.
- USask researchers were key to the recent mapping of the complete wheat genome so that scientists can now decipher the genetic basis of important traits in wheat, and produce better varieties of this essential grain to help feed the world.
- The USask Crop Development Centre has released more than 400 commercial crop varieties and continues to improve existing crops, and develop new and better ones.
- With one of the world's most advanced containment level 3 vaccine research facilities, our International Vaccine Centre is addressing infectious disease threats to advance human and animal health and food safety.

Working together with strong partners throughout Canada, across industries and beyond geographical borders, we will find safe, sustainable solutions for global food security—one of the world's most pressing needs.



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