INFINITY

SCIENCE
DISCOVERY
2019

Who's Tracking the Fireballs?

Finding the Blackout

When Insecticides Don't Work

Feeding a Hungry World

INAUGURAL 1 ISSUE

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Welcome to the launch of

INFINITY

Dear Reader,

This publication is designed specifically to reach out to Canadians and the world to invite you to follow the amazing science research taking place at Western University. Brought to you by the Faculty of Science, INFINITY is written so that industry innovators, government decision-makers, special interest groups and you, the curious public, can all benefit from a quick read of our short-form stories.

In this inaugural issue, we give you insight into the science of fireballs from space and earthquakes; natural hazards that can change the face of the earth in the blink of an eye. *Feeding a Hungry World* and *Pest Genomics* explore the topics of genetic modification, fish farming and pest control. Read *Tipping the Scales* to become acquainted with climate research at Western as our experts share their investigations about boreal forest death, the process of mercury poisoning of the watershed and the shift of northern peatlands from carbon sinks to carbon sources. Given the increasing number of wildfires across North America, you can't afford to ignore our research into forest fire prediction on page 20.

Then dive right in to stories about the design of innovative new imaging materials for health diagnostics, nuclear waste containment, and organic polymers that increase crop yields, offer exponential data storage capacity and water filtration for remediation of mining sites. To cap off your scientific enlightenment, read about the smart power grid systems being designed to reduce the time it takes to track and repair the source of blackouts.

If you have questions or want to know more, please feel free to visit our website at uwo.ca/sci or follow us @westernuscience. We are always happy to discuss opportunities to work together on these and other important scientific questions. Just refer to the quick contact information on the back cover.

Discover science with Western Science and be prepared to be amazed!

Dr. Matt Davison

Dean of Science
Western University

PEST GENOMICS: Protecting Canada's Agriculture Industry

Agriculture has defined Canada's economy and large parts of its culture for centuries, predating the arrival of European settlers and forming a significant part of our present and future national interests. From P.E.I. potatoes and Niagara's vineyards to the seemingly endless wheat fields of the prairies and bountiful orchards of the Okanagan Valley, Canada's very identity is shaped by our harvests feeding billions of people around the world. While an ancient practice, farming has faced technological advancement and biological innovation more reminiscent of a state-of-the-art laboratory than Monet's bucolic sceneries. Rapidly increasing population, changing consumer demands, and growing concerns of sustainability have all contributed to a rapidly evolving agricultural landscape.

Few areas of agriculture have faced such a combination of innovation and sociopolitical concern as the use of pesticides. Maximizing crop yields while minimizing the cost burden to farmers and risks to human and environmental health is the central issue of pesticide application. Canadian farmers are at the mercy of myriad factors but perhaps none so universally devastating as the spider mite, an insect pest that attacks over 150 agricultural and greenhouse-grown crops, including corn, soybeans, tomatoes, and cannabis. Although mainly controlled with the application of pesticides, spider mites are already resistant to all classes of pesticides currently used, which makes controlling them almost impossible.

Globally, nearly $1.5 billion are spent on mite-specific pesticides; insects are responsible for up to 25% of crop losses, totalling $470 billion annually. In Canada, losses from the vegetable industry alone totals nearly half a billion dollars.

Vojislava Grbic from the Biology Department at Western University and her husband, Miodrag, lead a research group that has single-handedly turned a non-existent area of study into a world-leading field. In 2009 they made a major breakthrough by sequencing the entire spider mite genome, allowing them to focus, at the genetic level, on exactly how these mites are capable of being such an elusive pest. This foundation is what allows them to currently work on pesticide and transgenic crop solutions to target specific genes in the spider mite, reducing crop losses while being completely safe for humans. Collaborating with Canadian farmers, growers' associations, and the Ontario Ministry of Food, Agriculture, and Rural Affairs (OMAFRA), the Grbic research group has engaged a variety stakeholders in Canadian agriculture to develop solutions while taking into account the diverse requirements of the entire growing process, literally from farm to table.

> “Most insect herbivores can only consume a narrow range of plants; spider mites can feed on over 1,100 species.”
>
> — **VOJISLAVA GRBIC**
> Department of Biology, Western University

Spider mites are resistant to all classes of pesticides currently used on them and can develop resistance to new pesticides in 2-4 years.

RESULTS

The direct results of the research from the Grbic lab will save Canadian farmers millions of dollars in lost productivity while simultaneously reducing the cost necessary to control pests. Additionally, their crop solutions increase predictability and security of food production, ensuring livelihoods for farmers. For consumers, this equates to a lower cost of food with substantially lowered exposure to chemical pesticides; in fact, 75% of active chemical ingredients will be phased out of pesticide use in North America and Europe over the coming years. By sharing the spider mite genome sequence with researchers around the world, the Grbics have created a community of scientists focusing on various aspects of pesticide resistance which have promising results for the future of agriculture.

Global warming supports faster expansion of spider mite populations and their outbreaks under hotter and drier conditions.

750 out of 1000 active chemical ingredients used in pesticides will be phased out in North America and Europe over the coming years.

FEEDING A HUNGRY WORLD

With the largest coastline on earth and more lakes than the rest of the world combined, it comes as little surprise that fisheries form a large part of Canada's heritage and natural resource economy. School children are taught the lore of the Portuguese fisherman centuries ago who could dip a basket into the waters off our Atlantic coast and lift it out, full of cod; however, the harrowing reality for thousands of Newfoundlanders in the 1990's when the cod fisheries collapsed serves as a sharp reminder that sustainable stewardship of our plentiful resources is paramount. Like farming, fisheries have faced rapid change in technologies and policies, propelling the industry into a future fraught with questions of how to feed an exponentially growing human population while safely stewarding a sensitive natural resource.

Leading this charge into the future of fisheries is the practice of fish farming, also known as aquaculture. While providing a source of fish that does not devastate wild fish populations, aquaculture raises its own issues of ethics and cleanliness, making it a divisive topic in public and policy spheres alike. Some farmed fish are kept at high densities and in close proximity to one another making disease transmission easier, and their waste and uneaten food can be sources of contamination to coastal waters surrounding the fish farms.

Bryan Neff and his lab group in the Biology Department at Western University are researching best practices for ethical and sustainable aquaculture by using advanced genetic techniques and collaborating with Canada's Department of Fisheries and Oceans as well as aquaculture companies.

"We use genetic tools to identify the salmon with the best traits for breeding, much like is done with horses or dogs," says Bryan Neff. They sequence salmon genes to find individuals with naturally high levels of immunity and growth rates, and then breed those individuals for production.

Farmers can reduce their reliance on antibiotics when fish populations have naturally high immunity, and fish with high growth rates use food efficiently to produce larger quantities of meat for the market. Farmed salmon are fed a diet of fish meal which is made from smaller fish, such as anchovies. These smaller fish are harvested around the world, often off the coasts of countries dumping chemicals in their waters and can be a source of toxins to fish in aquaculture communities. To make matters worse, these feed fish are being harvested to extinction, raising the issue of sustainability in salmon farming. Alongside genetic research, the Neff lab is researching sustainable diets for aquaculture with the goal of replacing fish meal while maintaining high levels of omega fatty acids in the farmed salmons' diets, benefiting consumers and ultimately the health of our oceans.

“We use genetic tools to identify the salmon with the best traits for breeding, much like is done with horses or dogs.”

— **BRYAN NEFF**
Department of Biology, Western University

50M	x	25%	=	$25B	+	3B
TONS OF FISH Farmed Annually		REDUCTION in Feeding Costs		ANNUAL SAVINGS		PEOPLE FED

RESULTS

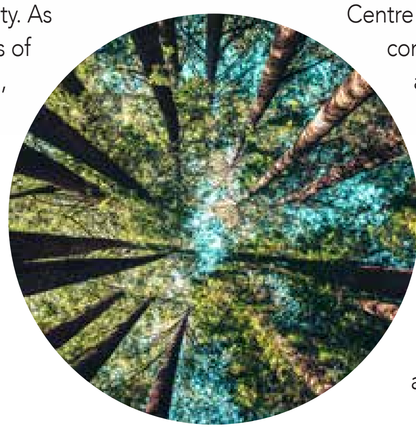
Feeding farmed fish represents the largest single cost in aquaculture (up to 50-70% of total costs); Neff’s research into breeding fish with greater growth efficiency reduces feeding costs by up to 25% — on the global scale that would equate to around $25 billion saved annually. Currently, about half of the fish consumed by humans comes from aquaculture and the industry is growing at a greater rate than the human population. Globally, fish forms a significant (20% or more) part of the diet of over three billion people. Cost savings across the industry, even small percentages, will have massive implications for the ecological sustainability and food security for people around the world, as demand on natural resources, alongside the human population, grows exponentially.

TIPPING THE SCALES
of Global Ecology and Climate Stability

Perhaps it is impossible to overstate the magnitude of the boreal forest in Canada; covering approximately 2.7 million square kilometers, half of the country's landmass is dominated by iconic coniferous forests. Defining Canada's northern landscape, boreal species are uniquely adapted to harsh and cold climates, thriving through long winters and strong seasonal variations in temperature and precipitation. The boreal forest represents a region of enormous economic and cultural significance for Canada. Forestry revenue from the boreal forest amounts to over $40 billion annually and the forestry industry employs around 130,000 people. Seventy percent of Indigenous communities in Canada live in forested areas, along with some of Canada's most well-known wildlife species, such as wolves, grizzly bears, and caribou. While the biodiversity of the boreal forest is limited due to extreme conditions, the vast size of the boreal region means that the forest carries out the essential functions of air and water purification, and carbon sequestration at globally significant levels.

> "While we know that climate influences trees, the trees also influence the climate."
>
> **— DANIELLE WAY**
> Biotron Experimental Climate Change Research Centre

Canada's seemingly endless landmass makes it a key player in global carbon, water, and climate dynamics. One third of the world's forests are boreal, from Canada, through Scandinavia and Eurasia. It is the largest forest type on earth and draws down around 95 million tonnes of carbon dioxide (CO_2) annually in Canada alone. Such vast numbers prove the boreal forest to be of paramount importance to global ecology and climate stability. As climate trends are changing, however, the effects of warming, on a forest system adapted to the cold, are tremendous. The coniferous trees forming the foundation of boreal ecosystems do not respond positively to warming climates, and, as a result, carbon sequestration by the forest may be significantly reduced. In recent decades, we have already seen increased mortality rates of boreal trees as higher temperatures and drought stress tip them into a negative carbon balance.



Danielle Way from the Biology Department at Western University leads a lab group researching the myriad effects of a warming climate on the boreal forest. At a large scale, increasing temperatures reduce the forest's ability to sequester carbon, resulting in a build-up of atmospheric CO_2 that then causes temperatures to rise further. Her team works at the Biotron Experimental Climate Change Research Centre where they can mimic future predicted climate conditions, including warmer temperatures and high atmospheric CO_2 concentrations, and examine how boreal trees will fare over the coming century. Way's team is currently collaborating with the Canadian Forestry Service, as well as the US Department of Energy on a multi-million-dollar project to study increasing temperature and CO_2 effects on living, mature boreal species. As her group expands, they are also investigating climate effects on significant crops, such as canola, and plant relationships with pollinators.

RESULTS

The Way lab's research adds to the accuracy of predictive climate models at home and across the planet while contributing new knowledge to assist in the development of mitigating strategies to counter increasing tree mortality in the boreal forest.

TOXIC WATER = DEADLY FOOD

Communities all over Canada have iron-bound ties to fishing, whether it be remote northern communities who have long relied on fish for their subsistence, or the millions of Canadians who fish recreationally, regardless of the season. Many people are aware of the risks of consuming too much tuna sushi – high levels of mercury accumulate in the tissues of large fish and can have health effects on humans. But in the Canadian context, consumers of freshwater fish from our own lakes sometimes must be cautious of elevated levels of mercury due of the pollutant's global footprint.

> "The timing of mercury release from watersheds to lakes is dependent on organic matter decomposition, which is directly affected by moisture and temperature, both of which are directly tied to changing climate."
>
> **— BRIAN BRANFIREUN**
> Department of Biology

Although many may think of mercury as a silvery liquid metal, it also exists as a gas in the earth's atmosphere. It gets there naturally from sources like volcanoes, but human activities have increased the amount in the air by between 2 and 3 times; the largest human sources are currently from small-scale gold mining and coal burning for power generation. This mercury in the air comes back to the Earth's surface in rain and snow, and is also taken up by plants. Once in the soil, it is slowly released via the decomposition of organic matter, such as leaves and wood, and is moved in water through watersheds into streams and lakes. It can then be turned into a form of mercury (methylmercury) that can be taken up by and accumulated in living organisms. There are consumption advisories for fish in lakes across Canada because of mercury, even in northern lakes far away from any industry. These advisories in the north present a major concern to the food security of these communities, where fish are an important traditional source of protein and food from the south is very expensive.

Brian Branfireun and his research group in the Department of Biology at Western University are investigating the landscape processes that take mercury from the atmosphere, process it through organic matter cycling, and finally export it to streams, rivers and lakes. His work on the processes that affect mercury movement in watersheds is linked to fish and other aquatic organisms through collaborative partnerships with other researchers, government agencies and local communities.

"Mercury isn't just emitted from smokestacks and then falls from the sky into lakes", says Branfireun – the microbes in soils that interact with mercury play a central role in determining the form of mercury entering a lake, and thereby the levels in fish. To make matters even more complex, changing climates have profound effects on these processes; higher temperatures in the north are not just warming the air, but are also changing amounts of snowfall and the rate of permafrost thaw. Permafrost is especially important because it contains trapped mercury and soil carbon which are potentially released as the rates of permafrost thaw increase.

RESULTS

The Branfireun group is contributing data that will allow for the development of predictive landscape models to help assess in which watersheds fish will be more susceptible to mercury accumulation, now and into the future, guiding policies about mercury risk in the multitude of lakes found in Canada's north.

CARBON SINKS TO CARBON SOURCES:

Predicting the Shift

Of the myriad questions and answers to global climate change issues, many can be distilled down to carbon economics – how much is being put in the atmosphere versus how much is removed. Heavy on the minds of many are the lowering of emissions through technology and the essential roles played by forests and oceans in capturing and storing vast quantities of carbon. But beneath all of these, quite literally, is a carbon pool perhaps more dynamic than any other, and with immense consequences on climate change – namely, soils. Especially in northern Canada; boreal peatlands amount to 3% of the earth's landmass while storing a third of global soil carbon. To put it in terms of carbon storage, every year boreal peatlands have the potential to capture and store about 13% of all carbon dioxide emitted by humans.

> "The soil microbiome is essential to turn decomposing organic matter into stable forms of stored carbon which cannot be easily released back into the environment."
>
> **— ZOË LINDO**
> Department of Biology

Dictating the ability of Canada's unique northern soils to act as a globally significant carbon sink are the dynamics of its seemingly-uncountable microorganisms. These microbial processes include the decomposition of organic matter from forests and agriculture, as well as a complex food-web of predators and prey – all of which is happening right beneath our feet. However, as the global climate is changing, these once-stable processes stand to change themselves, which will likely feedback on global climates. The water and nutrient dynamics of Canada's soil systems are extremely vulnerable to warming climates; the soil biodiversity and food-web structures are dependent on stability to continue functioning as they are. With drastic shifts in climate as we are experiencing currently, and as the soil species dynamics change, carbon will be released from soils at rates much higher than it can be absorbed and stored long term. The carbon storage potential of soils may be entirely reversed, and these once-dependable carbon sinks will become sources of carbon themselves.

Zoë Lindo and her research group in the Department of Biology at Western University are investigating soil microbiological responses to changing climates. By investigating the effects of increasing temperatures on soil species composition and rates of organic decomposition, the Lindo group is contributing to global climate models which predict climate trajectories into the future.

RESULTS

The Lindo lab has a long list of collaborations with provincial and federal ministries across Canada as well as the US Department of Energy. Policymakers, both in Canada and abroad, rely on these global climate models when implementing strategies to mitigate and/or reverse the effects of climate change. These models, in turn, rely on a detailed understanding of carbon dynamics. The often-forgotten, microscopic world beneath our feet forms a large portion of global carbon dynamics, and few systems are as globally influential as Canada's boreal peatlands.

FIREBALL HAZARDS IN SPACE AND ON EARTH

Once considered the final frontier, space is no longer an abstract concept. We have landed on the Moon, launched observation satellites to Mars and other planets in our solar system, and explored the Martian landscape with rovers on multiple occasions. Since the first telecommunications satellites took up positions in their geostationary orbits, space applications have become ever-more present in our daily lives. From texting and tweeting to NORAD defence systems, all Canadians are united by the growing need for reliable and secure access to space. Thousands of spacecraft, including satellites perform crucial functions while navigating the hostile environment of low-Earth orbit.

To the naked eye, shooting stars are magnificent streaks of light searing across the night sky. A closer look reveals their rocky reality. Travelling at dozens of kilometers per second, these meteors, depending on their trajectories, pose a critical threat to our telecommunications infrastructure. Much like a forecast considers numerous variables to predict possible paths of a hurricane, accurate forecasts of meteor showers and their potential impact zones are crucial to ensuring the endurance and function of assets in space.

Having an accurate picture of the meteor showers headed toward earth is essential for mitigation strategies to protect space assets; satellites can be re-oriented to minimize the likelihood of impact and shelter sensitive equipment from damage. Impact mitigation techniques result in satellites going off-line as they can no longer orient as required to perform their functions, and in the case of defence satellites, for example, this can be perilous. Therefore, high-resolution tracking of meteor showers can ensure the highest degree of safety for satellites while minimizing loss of function.

Research by Peter Brown and his colleagues Margaret Campbell-Brown and Paul Wiegert, as well as their collaborations with government and industry partners globally, positions Western University as a world leader in planetary defence. The Brown group's fully-autonomous meteor observatories are on the pioneering edge and provide exceptionally precise details of meteor trajectories and fragmentation, down to millimetre-sized pieces. This level of precision vastly exceeds the capacity of technologies available in the rest of the field today. They are also creating predictive models for incoming showers, augmenting detailed forecasts beyond simply the observable characteristics.

> "The meteor fronts we track travel at 60 times the speed of sound. At that pace we have to be right about their trajectories the first time."
>
> **— PETER BROWN**
> Department of Physics & Astronomy

RESULTS

The direct result of this research safeguards global governmental and industrial investments in telecommunications and defence. This saves billions of dollars annually on repairs while minimizing disruption to the essential services accessed from the ground.

The total replacement value of telecommunications satellites currently on orbit is estimated between 100 and 200 billion dollars. However, the importance of this research is not restricted to low-Earth orbit. Smaller meteors impact the earth on a daily basis, and on average, a meteor of greater size strikes the earth annually, causing an explosion equivalent to 5,000 tonnes of TNT. As recently as 2013, a meteor exploded over Chelyabinsk, Russia causing over $60 million US in window damage. More than 1,500 people sustained injuries caused mainly by flying glass shards, as well as ultraviolet burns.

After the Chelyabinsk explosion, governments and scientific communities around the world turned to Peter Brown's analysis of the meteor and its subsequent devastation in order to gain a better understanding of the tangible cosmic threats posed to our planet and infrastructure. Analysis by the Brown group of the Chelyabinsk fireball has redefined the parameters used globally to characterize incoming meteors as being potentially damaging to human life and infrastructure.

Results continue to improve meteor detection and tracking techniques so that detailed and accurate communications are now shared with inhabitants of predicted impact zones. With high-resolution meteor tracking and analysis, governments know with much greater certainty which outcomes to expect and how best to act in order to minimize panic and casualties.

ON SHAKY GROUND?
Improving Geotechnical Engineering Practices

HAZARDS

As our understanding of underground events has increased, we have included seismic safety standards in our building and bridge codes to ensure the longevity of crucial structures upon which millions of Canadians rely every day. Determining how and where to build, however, depends on a detailed understanding of the ground beneath our feet and how it changes during an earthquake. To add further complication, different types of soils respond in different ways. Improving geotechnical engineering practices requires a high-resolution image of the subsurface – a costly and impractical affair using current methods.

Sheri Molnar and her research group in the Department of Earth Sciences at Western University are developing new methods to survey the ground. Traditionally, 30-metre deep boreholes have been used to gather information about the ground upon which future building projects are planned. Each borehole costs about $3000 and only gives a profile for a tiny radius of a few centimeters. The Molnar group's new non-invasive method uses on-ground sensors rather than boreholes and, for the same price, can give detailed information for an entire city block.

RESULTS

Recently, the Molnar group was awarded a $3.5 million grant from Emergency Management British Columbia (EMBC) to provide seismic hazard mapping for the metro Vancouver area. The six-year project, ending in 2023, will give EMBC crucial information on shaking amplification factors, landslides, and liquefaction. This data is precisely what informs land-use planning, building codes, and safety retrofits for the millions of inhabitants in hazardous areas. The cheaper, more scalable, and less invasive technique that the Molnar lab has developed can be applied to cities around Canada, ensuring a higher degree of safety for building integrity than ever before possible.

The research group is currently leading an effort to create international guidelines for non-invasive geotechnical engineering methods to bring this critical improvement to countries across the globe that experience high levels of seismic activity.

KEEPING NUCLEAR WASTE OUT OF THE WATERSHED

Spent nuclear fuel appears as a simple bundle of metal rods but the processes of storing them safely are necessarily complex. The initial issue addressed in nuclear waste management was the prevention of groundwater contamination; one of the present-day hot topics is how to design a safe and affordable container for the radioactive waste. Until recently, the plan was to encase the spent fuel in steel, then slide it into an even larger copper encasement. The copper metal has excellent corrosion resistance and allows for safe, long-term disposal of the used nuclear fuel. However, Canada does not have the capability to produce the copper casing required for this because we lack the elaborate equipment needed, and thus this would be an expensive component of our nuclear program.

James Noël and David Shoesmith of the Department of Chemistry at Western University lead the Electrochemistry and Corrosion Science Centre where they study the longevity and reliability of alternate copper encasement methods. By either spraying the steel case with copper micro-particles or electrocoating it with copper, the group has found novel techniques to safely encase the nuclear fuel, reducing the thickness of the copper needed from 2.5 cm to only 3 mm.

Their respective labs collaborate with other countries around the world with nuclear capacity to achieve the common goal of continued safety of nuclear waste. Dr. Noël recently secured $12 million in funding to examine the safety of waste storage from a multi-dimensional perspective; he now leads a team of metallurgists, synthetic chemists, civil engineers, and microbiologists, all working to test the safety of the containers. This holistic approach to ensuring the safety of nuclear repositories is supported by a combination of institutional and private-sector funding. The long-term goal of this team will be to apply their methods to waste containment across several industries in Canada, including mining and oil extraction. They also collaborate with first nations communities, many of whom are often the hosts for remediation and containment sites.

RESULTS

These new methods eliminate concerns of seams and welds in the casing and can be carried out here in Canada; the total cost savings for the nuclear waste disposal program amount to $3 billion.

Canada continues to model the highest standards for safe handling and storage of nuclear waste and in the often tenuous world of energy politics, nuclear energy remains a robust and reliable base load upon which Canadians can continue to rely.

CHANGING THE USES FOR NATURAL RESOURCES

Whatever the motive was to refer to Canadians as "hewers of wood and drawers of water," it is impossible to deny the foundational role played by natural resources in the Canadian economy. The seemingly endless national fabric weaving together fishery, forestry, prairie wheat, and oil forms a distilled Canadian identity both for us and the international community looking in. Nowadays, the natural resource sector accounts for about 17% of Canada's gross domestic product and employs nearly two million people.

Current methods and applications for resource exploitation are polarizing topics. Add to this the impact of a rapidly changing global social, political and economic landscape and questions emerge about the future of Canada's natural resources.

Leading the charge to answer is Giovanni Fanchini from the Department of Physics & Astronomy at Western University. Cross-appointed with the Department of Chemistry, Fanchini is a Canada Research Chair in carbon-based nanomaterials and nano-optoelectronics. At the heart of these areas of research interest is the idea of taking petroleum, one of Canada's core natural resources, and changing the way we use it. Specializing in creating new types of organic, carbon-based materials, Fanchini's research group is finding scalable advanced manufacturing techniques to revitalize traditional petroleum exploitation.

"Why burn our resources when we can build things from them, even forms of renewable energy? Increasing Canada's manufacturing output by revitalizing our natural resource economy with knowledge-driven content will ultimately make our resources last longer, making a lasting contribution to the economy."

– GIOVANNI FANCHINI
Department of Physics & Astronomy and the Department of Chemistry

RESULTS

Fanchini's group builds organic polymers from petroleum sources that have significant applications in water filtration and environmental remediation, data and information storage, and solar cells. Using advanced carbon materials for water filtration draws on existing resource pools like oil and graphite and creates high value-added products in the manufacturing industry. The carbon-based membranes have micro-pores, meaning they can filter even the smallest metal ions with greater success than traditional methods. This improves contaminant removal outcomes in mining and agriculture remediation.

Fanchini's group has also devised a way to substantially reduce the cost of solar cell production. Printing them from an oil-based carbon polymer produces solar cells that are as efficient as traditional silicon-based solar cells and more sustainable to manufacture.

Collaborating with the Gilroy lab in the Department of Chemistry, the Fanchini group is also using organic polymers to make ultralight data storage devices without using harmful solvents.

Using Canada's stocks of graphite, coal, oil, and even leftover agricultural feedstock to manufacture advanced, high value-added products, feeds our innovation economy, greatly slows the depletion of these finite resources and importantly, maintains jobs in regions of extraction.

CHANGING THE DIAGNOSTIC TOOLKIT

MATERIALS AND BIOMATERIALS

Recent Canadian-led developments in the field of sustainable materials research has made significant impact in several key areas including healthcare and sustainable manufacturing. Synthesizing materials that are simple to manufacture yet perform inherently complex tasks will continue to be a major source of cost savings in manufacturing, whether it be in electronics or medical imaging.

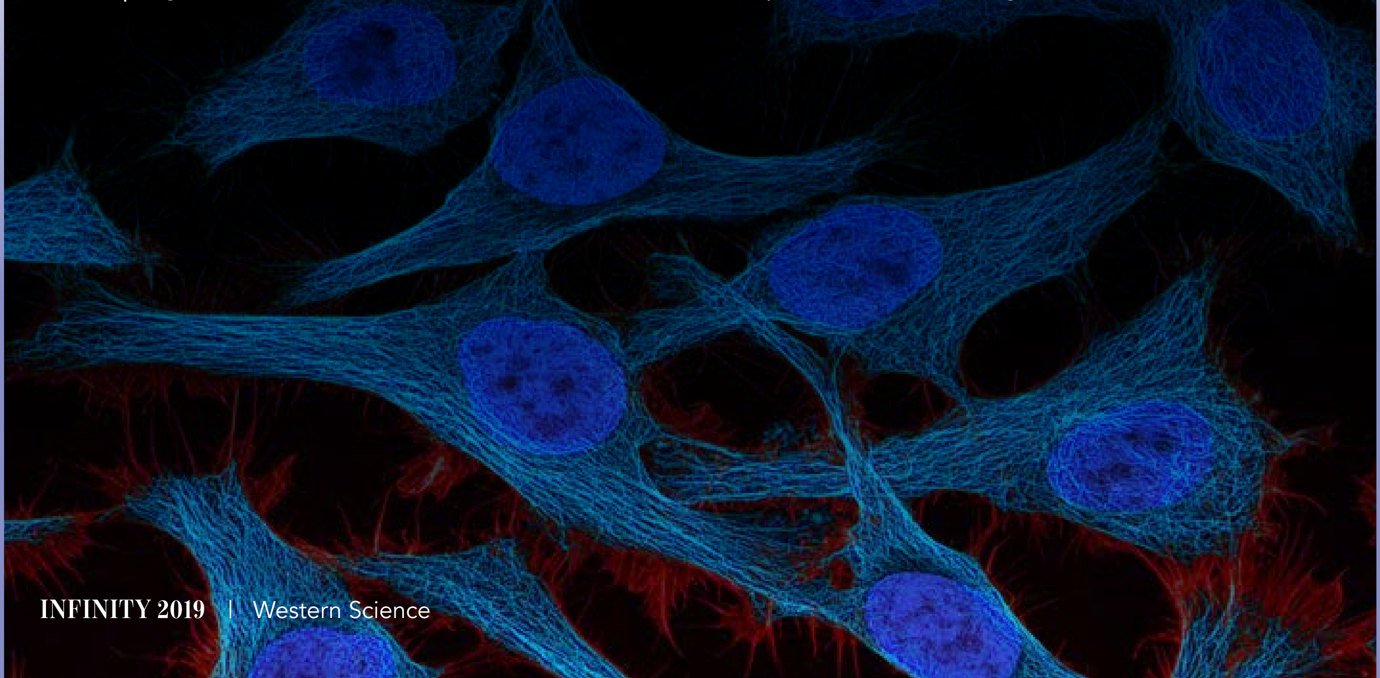
In Canada, over 200,000 cancer diagnoses were made in 2017, with 80,000 in Ontario alone. The materials used to build diagnostic medical tools, such as cellular imaging agents, are constantly being updated for improved performance. Included in those updates are improvements in the ways we build these objects, often to reduce manufacturing costs or the environmental footprint of the production process.

Joe Gilroy, Len Luyt and their respective research groups from the Department of Chemistry at Western University, have developed a new fluorescent molecular material capable of staining cells, outside the body for diagnostic imaging and are working toward the development of examples that will selectively stain diseased cells. If successful, this new material may be able to selectively interact with receptors expressed by breast cancer cells to differentiate them from healthy cells. Collaborating with colleagues specializing in bioimaging, the Gilroy lab is looking to expand the use of this new imaging agent which has the potential to save millions of dollars in diagnostic expenses in Ontario alone.

RESULTS

The imaging agent developed by the Gilroy group is much simpler to make than the materials currently used. It costs only $20-$30 per gram to develop, about 2000 times cheaper than current imaging agents that cost up to $50,000 per gram.

Having collaborated with companies like 3M to design new materials for industrial wastewater remediation and Firestone to synthesize stronger materials for automotive tires, the Gilroy group is keen to develop manufacturing techniques as novel as their high-tech materials.

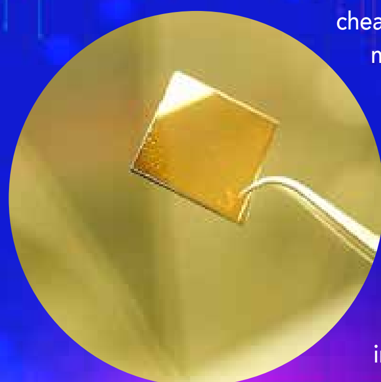


CREATING INEXPENSIVE AND EXPONENTIAL DATA STORAGE CAPACITY

Currently, most information storage, whether it be on servers or flash drives, are based on silicon media. Hazardous solvents play a central role in the manufacturing of alternative data storage devices based on organic materials and many of these solvents are known carcinogens or nerve-damaging agents. Minimizing the use of these solvents is a key concern for environmental and labour safety, especially as demand for data storage products is increasing rapidly.

Today's data-driven world has seen exponential increases in sensor proliferation and data generation. Accompanying this exponential increase in information generated is a soaring demand for data storage capabilities.

The Gilroy and Fanchini groups, from the Department of Chemistry and the Department of Physics & Astronomy at Western University, are synthesizing new materials for organic electronics that are cheaper and more effective than traditional materials and will potentially eliminate the use of toxic solvents. Gilroy and his colleagues have developed a new method of memory storage by using an *organic* polymer rather than the traditional silicon-based materials. This new polymer is between three and eight times thinner than existing memory storage devices and, crucially, minimizes the amount of harmful chemicals required in its synthesis.



RESULTS

The Gilroy and Fanchini groups are now working on scaling up the manufacturing process for this ultrathin polymer which would allow it to be reworked for a range of devices including OLED televisions, transistors, and solar cells. In the booming field of Big Data, a central issue is the manipulation and storage of vast amounts of information; this new polymer provides a much-needed opportunity to reduce costs for the industry while simultaneously increasing data capabilities.

WORLDWIDE DATA STORAGE MARKET

$30 Billion
2017 VALUE (USD)

21%
PROJECTED ANNUAL GROWTH

$96 Billion
VALUE BY 2023

THE ORGANIC SOLUTION TO EFFICIENT FERTILIZER UPTAKE

The application of fertilizer to increase the yield and security of agricultural crops is a practice dating back to the times of the ancient Egyptians and Romans. Facing countless key modernizations over the last centuries, agriculture now faces contemporary issues such as climate uncertainty and environmental sustainability. In an industry of often slim margins, farmers depend on reliable and affordable fertilizers to maximize crop yields. They are also forced to contend with a changing environment for which history has no precedent, making agricultural innovations, especially in the fertilizer industry, all the more indispensable. Currently, to obtain a given yield of crops, farmers must over-apply fertilizers to their field; the production of nitrogen-based fertilizers is massively energy intensive.

Inefficient use of fertilizer is a cost to farmers and damaging to the environment; excess nitrogen from fertilizer runoff has been the cause of significant environmental tragedies like the Lake Erie dead zone and increased nitrous oxide emissions in response to fertilizer application are a significant source of global greenhouse gases. A key issue in the application of fertilizers is that they are applied typically at the beginning of the planting cycle of crops, because once the crops are growing, it is often difficult to apply fertilizers again. This means that farmers apply far more fertilizer in one dose than can be taken up by plants, and often at not at the time when the plants need it most. This creates fertilizer runoff into nearby bodies of water and nitrous oxide gas accumulation in the atmosphere.

Elizabeth Gillies, Hugh Henry, and their labs are researching an organic polymer coating for fertilizer pellets to improve their use efficiency for crops. Recent research has shown significant increases in crop yield and fertilizer uptake efficiency when fertilizers are coated with plastic polymers – the polymers eventually degrade over time, and the fertilizer gets taken up by crops. But the polymers presented a new problem: they were introducing micro-plastics into soils and water. The Gillies and Henry labs are building new polymers from organic compounds which are able to deliver a specifically time-targeted release of the fertilizer without contributing to an increasingly toxic global plastic build-up.

RESULTS

Creating organic polymers for fertilizer application will simultaneously reduce the financial burden on farmers from having to over-fertilize early in the crop cycle, increase crop yield and security, minimize environmental damage from nitrogen runoff and emissions, and eliminate a source of microplastics in agricultural soils and water. Current polymer coated fertilizers have resulted in reduced nitrous oxide emissions by up to 40% and reduced nitrogen leaching into soil by up to 20%, all while maintaining or even improving crop yield. These improved efficiencies give farmers the crop security they need while minimizing costs and environmental damage.

SMART POWER GRIDS:
Tracing the Blackout and Reducing Downtime

More than just occasional nuisances that force us to unearth our candles and flashlights, electricity blackouts can be a source of safety hazards and significant economic loss. Nearly every facet of modern life depends on electricity – now more than ever before. As an increasing amount of our lives is stored on and accessed from cloud servers and more of our devices are connected and responsive to one another, our dependence on reliable electricity will only escalate into the future.

Electricity blackouts are often caused by physical breakages in the supply grid, as the electricity is transported from the point of generation to distribution centres that deliver the electricity to consumers. Predictably, the more complicated the power grid, the more difficult it is to locate the cause of the blackout, which needs to be established before repair actions can take place. Time is most often lost finding the defect, as current methods rely on consumer reporting and trial-and-error detecting, both of which are woefully inadequate. Updated methods of precisely locating the source of blackouts are required for faster grid repairs as demand for consistent and reliable electricity continues to rise.

Hanan Lutfiyya, Anwar Haque and their research groups from the Department of Computer Science at Western University, are working on "smart power grid systems" to better trace blackout points in the grid and resolve them faster. By implementing a system of sensors on an electrical grid, their groups are able to accumulate large amounts of electrical data which they can use to locate faults on the line with precision.

RESULTS

The sensors themselves are relatively small and inexpensive, giving them the potential to create significant savings in both time and money otherwise required for traditional grid repairs. Hanan Lutfiyya and Anwar Haque have partnered with Tillsonburg Hydro – a power company currently serving around 7,000 customers – and are in the process of implementing their system on the Tillsonburg grid. Having a real-world partner means that the group can not only test their system but also optimize it to further reduce costs.

As the data rolls in from the partnership with Tillsonburg Hydro, the Lutfiyya and Haque groups will seek to make improvements on their novel system and make it scalable to larger, more complex power grids. Minimizing the number of sensors required to precisely locate grid defects while still maintaining precision will be the key to scaling up the Lutfiyya/Haque group smart grid system.

FOREST FIRE PREDICTION

Saving Lives, Ecosystems, Economies and Jobs

In a country with millions of square kilometers of forests, Canadians are acutely aware of the dangers of forest fires. Standing out in the minds of millions are infernos such as the 2016 Fort MacMurray wildfire which saw tens of thousands of people evacuated and approximately $10 billion in damage. 2017 was the third consecutive year of above-average forest fire impacts; 5,600 forest fires burned 3.4 million hectares, causing hundreds of millions of dollars in damage.

While fires are often a natural process in forests, climate projections show that forest fires will likely become more frequent and intense as we enter a period of greater climate uncertainty and above-average temperatures.

Long behind us are the days when the most cutting edge fire-fighting tools were airplanes with bellies full of water. While instrumental in wildfire suppression, typical methods are nowadays being supported by advanced data-driven tools to support decision-making. Synthesizing patterns of human land use, forest dryness and weather, information scientists can contribute to modern firefighting by creating predictive models that interpret these data structures and derive patterns using advanced algorithms.

Douglas Woolford and his research group in the Department of Statistical & Actuarial Sciences at Western University are using modern data science to better understand wildland fires. They are able to use complex data structures to gain an understanding of patterns in key characteristics of wildfire regimes and integrate that knowledge into wildfire management. Using large, complex datasets from across the country, the Woolford Wildland Fire Science Lab develops models to create risk maps which can help predict where fires may occur given current weather conditions. The models will help fire management forces decide how best to allocate resources and personnel.

"The idea of these models is to be a form of decision support."

— DOUG WOOLFORD
Department of Statistical & Actuarial Sciences

RESULTS

The Woolford group's models are already being used. The Ontario Ministry of Natural Resources and Forestry has been using their models to create fire occurrence prediction maps daily through recent fire seasons. The output from such models feeds into systems such as the Aerial Detection Demand Index, which integrates spatial maps of fire occurrence risk, potential fire behaviour and values on the landscape into a single index that identifies priority areas for detection efforts.

Woolford is currently collaborating with other researchers and fire management agencies on projects that will produce fire occurrence prediction models for the Province of Alberta, as well as a national fire occurrence prediction system. Being able to predict when and where fires can occur will give us a much-needed advantage as we see the severity and frequency of forest fires increase in the coming years.

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