RCIScience

2018 Annual
(Annual Report Edition)

MAGAZINE

WHOSE GENOME IS IT, ANYWAY?

Weighing the benefits of knowing about ourselves

THE SCIENCE OF SPARKLING WINE

Deconstructing our favourite bubbly

THE PLANETS

What do planetary science and music have in common?

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RCIScience
Royal Canadian Institute for Science

COVER PHOTO: *By Johannes Groll. Aurora borealis, northern reflections: a Canadian theme reflects RCIScience's goals to expand our programs nationwide, all while fostering our sense of wonder.*

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Letter from the Editors

WELCOME TO THE INAUGURAL EDITION OF THE RCISCIENCE MAGAZINE!

We live in a great country, but one thing Canada lacks is its own science magazine. This inaugural edition of RCIScience Magazine is a small step towards remedying that.

Here, we'll explore the fascinating science happening in Canada and meet the scientists conducting the research behind it, starting with a few we encountered during our 2017-18 season of public programs in Toronto, Mississauga, Ottawa and Waterloo.

This is a bit of return to our roots. The Royal Canadian Institute published its first *Canadian Journal* in 1852. After that came the *Proceedings*, then *Transactions of the Royal Canadian Institute*. We published regularly into the 1950s, then more sporadically, until finally ceasing regular publication in the early 1970s. In 1999, *Special Places* was published to commemorate the 150th anniversary of the Institute.

Those early *Journals* and *Proceedings* form a record of research in early Canada and copies are held widely across the globe. You can find many of them digitized online and there are complete sets in libraries across Ontario.

Reading these old journals gives a snapshot of the state of science and what people were concerned about all those years ago. Our hope is that RCIScience Magazine does the same for readers a century from now.

And what a wide range science spans in Canada! From the microbiome to distant planets; the chemistry of bubbles in sparkling wine to the genome of a beaver—there is a lot on offer in this magazine. We hope that you enjoy it and consider it a thank you for being a member and supporting RCIScience.

We hope to see you throughout 2018-19, and that you'll be reading another letter from us next Fall!

Kirsten Vanstone and Carrie Boyce

Message from the Chair

As this is the end of my two-year term as volunteer Chair of the RCIScience Board, I would like to say that it has been a great honour to serve RCIScience as its 114th Chair.

I would like to thank the members and sponsors of RCIScience for their continuing support which makes what we do possible. I would also like to thank the program partner organizations we work with for their support and the other volunteers I have worked with on our Board.

In particular, I would like to thank immediate past Chair Helle Tosine for her leadership in bring the RCIScience's governance up to a best-in-class status and for her hard work ensuring that the Ottawa programs got off to such a great start.

I am also delighted to know that RCIScience will be in such good hands under incoming Chair Professor Reinhart Reithmeier and thank him for the new ideas and vitality he has injected into the programs offered by RCIScience. And, of course, none of this would have been possible without the exceptional contribution of Kirsten Vanstone, our Executive Director; her enthusiasm and love of science are infectious.

Peter Love

RCIScience Experiments

A Reflection on the Past Year

As Canada's oldest public scientific society, no one would be surprised if there was a tendency to continue doing what has worked for the last 169 years.

That is not what has happened this year!

RCIScience embarked on a major expansion program in many areas.

We consider this to be a large and very important science experiment to see how RCIScience can best achieve its vision of an informed public that embraces science to build a stronger Canada.

Here is a short summary of what we have been up to as part of this exciting experiment.

GEOGRAPHIC EXPANSION

RCIScience has offered free, public science talks in Toronto since 1913, and we always will. A few years ago, we started to offer monthly talks in Mississauga. In 2015, we presented a 3-part series in Ottawa, Calgary and Vancouver. This year, we had a regular presence in Ottawa and Waterloo, which has proven that the RCIScience model can be successfully replicated.

Special thanks to Kat Tosine in Ottawa and Jenessa Doherty in Waterloo for making these events such a great success. Next year, we will be offering talks in all four locations as well as investigating other potential expansions.

The Promise & Perils of Gene Editing, panel discussion with the ISSP at the University of Ottawa. CREDIT: University of Ottawa

GETTING THE MESSAGE OUT

In the past, most RCIScience activity centered around weekly talks in a lecture format on Sunday afternoons at the University of Toronto. While we will continue to offer this type or programming, our schedule now features more panel discussions and other, innovative, ways to encourage science discussion.

During my tenure, these included a most successful venture with the Hart House Orchestra for a presentation of Gustav Holst's The Planets, peppered with recent scientific discoveries, a special 2017-18 Kick Off event featuring the science of sparkling wine and a special program for Syrian refugee families presented in English and Arabic.

In Ottawa, where science policy is paramount, we have hosted panels with the University of Ottawa's Institute for Science, Society and Policy, as well as at the Canadian Science Policy Conference (CSPC). These panels have been structured to include not only the science & technology, but the societal impacts and policy challenges they present. Beyond these talks, the inaugural edition of this RCIScience Magazine represents another innovation that we hope you will find of interest.

And thanks to our newest employee, Carrie Boyce, RCIScience has dramatically increased its online presence.

FUNDING

RCIScience now has two families that have committed to endow annual talks and is finalizing agreements with two industry associations to fund focused talks. This year also saw the expansion of multi-year funding from the federal government. We also organized a less formal fundraising event at Steamwhistle Brewery that will complement our more formal annual Science Dinner. While RCIScience still needs to become more effective at raising funds, it is important to note that the legacy endowment that RCIScience holds is just under $1.5 million, up 4% since February 2016.

PROGRAM PARTNERSHIPS

Working with other like-minded organizations has been a critical part of RCIScience's success. Building on 16 existing partnerships, we were delighted to welcome the University of Ottawa's Institute for Science, Society & Policy as a partner in our Ottawa programs and the Waterloo Libraries as a partner in our Waterloo programs.

VALUE PROPOSITION

Four years after developing the organization's first strategic plan, this year the board worked on developing a series of value propositions that better articulate the importance of RCIScience to our many stakeholders.

Special thanks to Helle Tosine, Immediate Past Chair of RCIScience, who led this important initiative and to Mary Tate of Optimus/SBR for volunteering to facilitate this session. Results will be published shortly.

Left to right: Ms. Helle Tosine, Immediate Past Chair, RCISCience; Dr. Mona Nemer, Canada's Chief Science Advisor; Dr. Monica Gattinger, Director Institute for Science, Society & Policy (ISSP), University of Ottawa. CREDIT: University of Ottawa

WHOSE GENOME IS IT ANYWAY?

By Christina Gulessarian

Genetic testing services are now widely available to consumers and the era of leisure genomics—using genetic sequencing for interest rather than academic research—has begun.

For less than $250, direct-to-consumer services collect and process DNA samples and provide a report outlining an individual's ancestry, wellness traits, the risk of developing a variety of diseases and a whole host of other information. This has far reaching implications for family planning and personal health, but there are limitations.

The risk of someone developing a particular health condition, for instance, is often unclear. Rather than analysing the three billion nucleotides that make up the human genome, these services focus on just 700,000 nucleotides that commonly vary in the human population and have been associated with different traits.

> ***"...we need to weigh the benefits of knowing so much about ourselves with the ethics and security risks..."***

CREDIT: National Human Genome Research Institute (NHGRI)

As Dr. Fritz Roth, Professor of Molecular Genetics at the University of Toronto, points out, “The variants that are bad for us are unlikely to have become common in humans because of their association with severe and fatal illnesses.” While analysing common variants is useful to link specific genes to specific diseases in a large population, it is not typically useful to predict an individual’s health risk. While genome sequencing can reveal those rare variants that are more likely to cause health effects, we usually cannot tell damaging from harmless variants.

Dr. Michael Szego, Bioethicist and Assistant Professor in the University of Toronto’s Dalla Lana School of Public Health, insists there are a number of medical and ethical considerations to keep in mind. For example, individuals who are biologically related share genetic information so any information obtained from genome sequencing will have implication for the individual who has been sequenced and their family members.

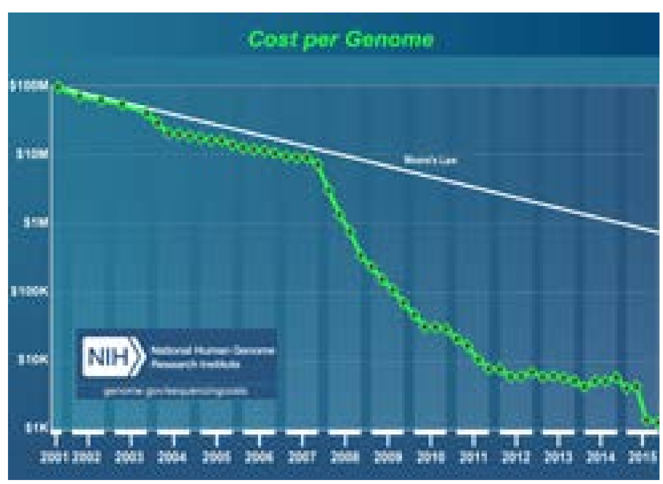
The Personal Genome Project Canada is a public genomics project where participants consent to have their genome sequenced and published on a public website. We recognize the familial aspect of genomic information by asking participants to speak with their family about their participation. This conversation is an opportunity for participants to learn about their family members’ views about their participation and whether they would want to know any medically relevant genetic information.

In another project called the 1000 Genomes Project, participants’ consented to have their genomic information and city of origin made public, providing researchers with a valuable resource. However, the 1000 Genomes Project also highlighted the privacy risks of sharing this data are not to be taken lightly. In one instance, a group took the publicly available data from the 1000 Genomes Project, compared it with an ancestry database and re-identified over 50 participants from the study. Whole genome data is unique to each individual, like a fingerprint, and therefore can be identifying.

Dr. Wendy Ungar, Senior Scientist at SickKids and Professor at the Institute of Health Policy, Management & Evaluation at the University of Toronto, considers the economic implications of genome sequencing in her research.
Dr. Ungar also chairs the Ontario Genetics Advisory Committee at Health Quality Ontario which is responsible for advising on which genetic tests should be publicly funded in that province. The committee analyses available evidence on clinical benefit, value for money, patient preferences and values for genetic testing technologies.

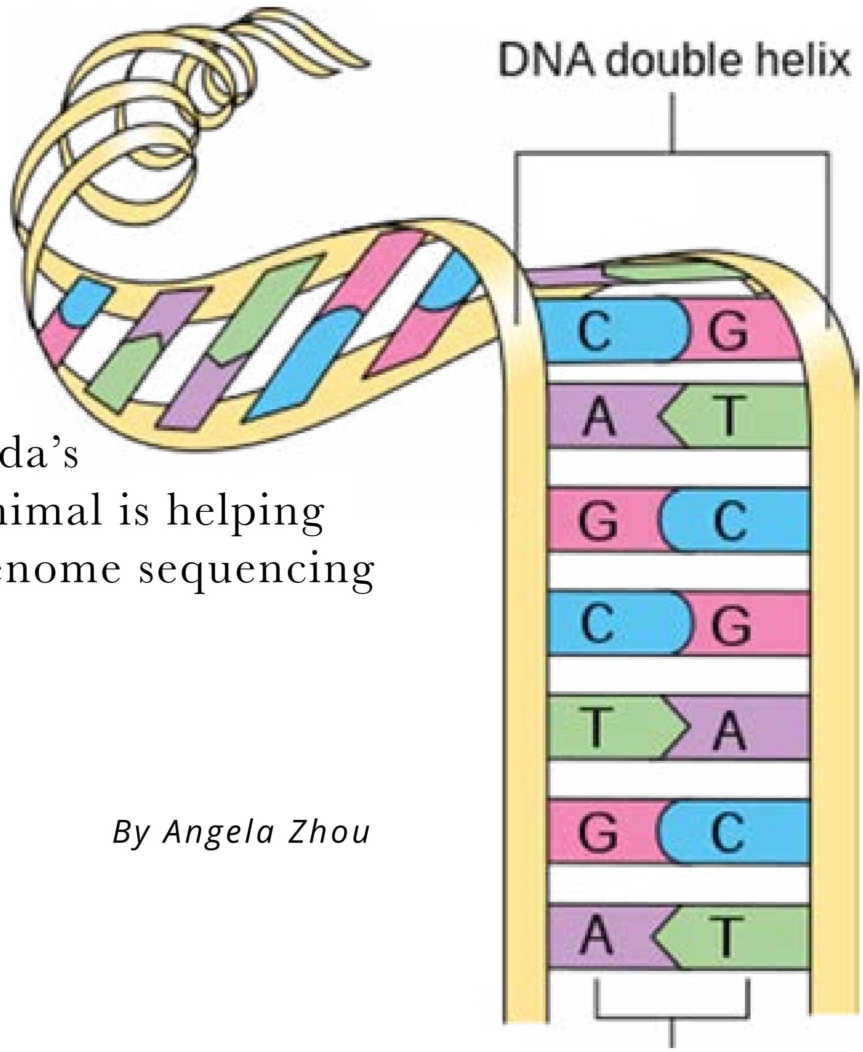
Dr. Ungar highlights that, while genome sequencing could help avoid unnecessary medical tests to determine the cause of a particular health issue, the discovery of additional or unexpected high-risk variants in a patient could add subsequent costs to the healthcare system as patients are monitored for these other conditions. She queries how much patients need, or want, to know about other identified risk factors, and how much should be shared with family members. The cascading impacts of genetic testing need to be carefully considered before being widely implemented in a healthcare context.

It remains to be seen whether leisure genomics will be more than a short-lived fad, but services like 23andMe and AncestryDNA are counting on our innate curiosity to find out where we come from and what we’re made of to fuel their business. In an age of data protection, we need to weigh the benefits of knowing so much about ourselves with the ethics and security risks associated with making such personal information readily available. In short, we should all ask ourselves, whose genome is it, anyway?



The technology to sequence genomes increased faster than computer processing speed, governed by Moore’s law. As sequencing speed increases, the cost decreases. CREDIT: National Human Genome Research Institute (NHGRI)

The Castor Code



How Canada's national animal is helping advance genome sequencing technology

By Angela Zhou

The code of life
Who you are is determined by your DNA - two long, entwined, complementary codes inherited from your parents that are comprised of adenine (A), cytosine (C), guanine (G), and thymine (T) nucleotide bases.

These bases are combined in unique combinations to make genes that ultimately define every little bit of you. The genetic material of an organism is collectively known as its genome: a master blueprint that instructs the characteristics of the species and the individual. Genome sequencing is a difficult and expensive process by which scientists map out this blueprint down to its constituent base code.

When Oregon State University launched a crowd-funding campaign to sequence the beaver genome, the Great Race was on. "It's our National animal, after all," remarked Dr. Si Lok, the Lead of Technology Development at The Centre for Applied Genomics (TCAG) from the Hospital for Sick Children (Sick-Kids) in Toronto, voicing the obvious concern that was on everyone's mind. Naturally, Canadians should be the ones to sequence the beaver.

No disrespect to Benny the Beaver, the Oregon State mascot who served as muse to the University's Beaver Genome Project, but *Castor canadensis*—if the species name doesn't already reveal it—is far more beloved and revered north of the border. The buck toothed rodent graces everything from pocket change to regimental badges of the Canadian Forces, a reflection of the importance of this animal in the development of Canada as a nation through the fur trade.

Thus, in 2015, with Canada's 150th birthday only two years away, Dr. Lok and his colleague Dr. Steve Scherer, the Director of TCAG, assembled an all-star Canadian team to tackle this genetic endeavour with the goal of completing it in time for the nation's sesquicentennial bash.

SickKids is no stranger to genomics research, and Dr. Lok was happy to chat with RCIScience and its members about the research institute's world-class facility in TCAG, its storied history of ground-breaking genetic discoveries, and their birthday present to the country – the genetic sequence of Canada's national emblem.

Sequencing technology has come a long way since its initial introduction. In 1977, Walter Gilbert of Harvard University and Frederick Sanger from the National Institute for Medical Research in London separately developed the first practical DNA sequencing techniques and were later awarded a Nobel Prize in Chemistry for these contributions to science.

Dr. Lok emphasizes the importance of this discovery to biomedical research by recalling that, "you cannot have graduated in the 1980s without sequencing something." Unfortunately, the technology back then only allowed 50,000 bases to be sequenced per week, which would equate to 10,000 years for an entire human genome to be completed.

In 1989, Leroy Hood developed the first automated sequencing machine, slashing that timeline down to 1,000 years to sequence the human genome. This ushered in the exciting era of genomics, starting with the sequencing of *Haemophilus influenzae* bacteria, the first organism to have its genome completely sequenced in 1995.

A year later, a species of yeast became the first eukaryotic organism sequenced, followed by the first multicellular organism in the form of a nematode worm in 1998. In 2000, the fruit fly was the first insect sequenced.

It was only a matter of time before the human genome was attempted, with government-funded scientist, Francis Collins and independent maverick, Craig Venter leading competing groups. Both groups published a first draft of the human genome in 2001.

Ultimately Collins's project cost approximately $3 billion USD when completed. The introduction of second-generation sequencing machines in 2007 caused a dramatic drop in the cost of sequencing, and investors jumped at the possibility of sequencing the human genome for a mere $1,000 – an accomplishment finally achieved in 2014.

The real reason behind the beaver sequencing project at TCAG was to test and showcase a new, cheap and precise sequencing strategy. Despite advances in sequencing technology, Dr. Lok is careful to make one important clarification. "The human genome is very long, comprising more than 3 billion characters. If printed, it would fill 200 phone books – that's a lot of information!". The problem is that sequencing machines producing the so-termed $1,000 genome can only deliver the sequence data as a collection of very tiny, randomly generated pieces - over 400 million of them for each patient. Typically, these tiny pieces, or short-reads, are not assembled together, but are simply mapped to the existing human reference genome (the one that cost $3 billion and took 13 years to construct). The differences are then tabulated. This mapping-based genome sequencing process is technically called resequencing.

"It is misleading in this regard," Dr. Lok explains. "You're not getting all of the information when using a resequencing process." For example, unsurprisingly, most of us have varying amounts of sequences that are not present in the published reference genome. These sequences and the genetic information contained in them are typically discarded since they would not map well or map at all to the reference genome.

The *castor canadensis* in its native habitat. Beaver populations may vary in different regions. The genome study looked at samples from Ontario and Quebec beaver populations. CREDIT: Wikimedia commons

DNA illustration showing a double-helix of a chromosome. CREDIT: Cancer Research UK / Wikimedia Commons

The obvious solution would be to eliminate the mapping process and the reliance on the reference genome altogether, and instead, construct the patient's unique genome from scratch using only the patient's sequence reads. This process is known as *de novo* sequencing and is computationally very difficult since genomes contain families of identical or repetitive sequences that are not readily resolvable by inexpensive short-reads. Dr. Lok likens this conundrum to, "an impossible jigsaw puzzle of over 400 million small pieces, in which many of the pieces are identical to one another."

One solution is to produce longer sequence reads that could span the repetitive regions of the genome. In our jigsaw puzzle analogy, this would be akin to making the puzzle pieces larger so that there are fewer of them, as well as reducing the number of confusing identical pieces. However, long sequence reads are less accurate and are far more expensive and slow to produce.

THE BEAVER IS AN INTEGRAL PART OF CANADA'S HISTORY.

To resolve this issue, Dr. Lok, Dr. Stephen Scherer, and their team proposed a hybrid method using a combination of short and long reads wherein the long reads themselves would serve as a guide to improve the precision of short read sequencing. This approach could help make *de novo* sequencing projects cost-effective and manageable. The project was funded by a grant from Genome Canada.

THE CANADIAN CANDIDATE

The initial plan for developing this hybrid sequencing approach was to use the DNA of Craig Venter, the visionary scientist associated with early attempts at sequencing the human genome. This plan changed after an event that Dr. Lok called, "The Walking Stick Incident," in which Dr. Scherer was on vacation with his family and became fascinated by a walking stick insect observed by his son. At that moment, Dr. Scherer entertained the idea of sequencing and assembling the genome of a non-human organism.

Not surprisingly, the Canadian beaver was quickly suggested. In addition to its status as a notable national emblem, using the beaver would offer insight into the biology of rodents, a group of mammals underrepresented in the genome databases. In fact, despite making up 40% of all mammalian species, at the time only 7 of the 28 families of rodents had been studied by genome sequencing. Among those unstudied was the Castor family, which contains only two species: the Canadian beaver and its Eurasian cousin. Therefore, the results of a beaver genome study would provide more information on the biology of this family of mammals, its ecological and evolutionary roles, and the effects of human activity on its survival.

The beaver is an integral part of Canada's history. This animal was first scientifically described in 1820 by German naturalist Heinrich Kuhl from a beaver pelt collected from Canada's Hudson Bay region. The species was formally named *Castor canadensis* for the "castoreum" gland at the base of the animal's tail and the species' recognised association with Canada.

Fuelled by European Fashion, the beaver fur trade helped drive colonial expansion in North America. Compared to the 18 or so subspecies of beavers living in the United States at the time, the originally described Hudson Bay population was deemed to have the highest quality fur. Therefore, this beaver was deliberately introduced into other locations across North America, mixing with or essentially replacing the local American beaver populations. As Dr. Lok points out, "There are no American beavers, only Canadian beavers living in the United States."

Further evidence of the beaver's economic impact, the North West Company began listing the value of their traded goods in "Made Beaver" units, in which one "Made Beaver" was equivalent in value to a male beaver pelt. The estimated population of 200 million beavers in North America was decimated by trapping and habitat destruction. The species was rescued only by burgeoning environmental awareness and the fickleness of European Fashion, which turned away from pelts and towards silk fabrics in the mid-19th century.

Sequencing the beaver was very much a cross-disciplinary endeavour. Dr. Lok and the TCAG team sampled populations from both of the historical Upper and Lower Canada regions: the former taken from frozen beaver muscle tissue archived at the Royal Ontario Museum (ROM) in Toronto, and the latter obtained from Ward, a beaver from the Saguenay-Lac-Saint-Jean region of Quebec currently living at the Toronto Zoo.

All sampling was performed from male beavers in order to acquire the entire genome, including the Y chromosome. The project not only advanced sequencing technology, it also provided valuable information on the health of the nation's beaver population (apparently healthy with plenty of genetic diversity!) as well as insight into evolutionarily-relevant genes involved in such areas as dental biology.

GETTING THE WORD OUT

Around the same time as Sick Kids started this project, Oregon State University answered a challenge issued to American universities to sequence the genome of their football team mascots. Oregon State's is the Benny the Beaver. The TCAG team was also able to beat them out, cleanly winning the Great Race and being the first to sequence, assemble and publish the beaver genome.

On December 6th, 2016, the team submitted their beaver genome manuscript for publication. In accordance with the long established scientific practice, the manuscript underwent peer-review by leading experts. The manuscript was published on February 7th, 2017 by the journal G3: Genes, Genomes, and Genetics, just in time for the Canada150 festivities.

G3 wanted to feature the study on its cover with an illustration that was visually appealing while appropriately reflecting the essence of the work. The perfect image came in the form of Canada's very first postage stamp issued in 1851, the striking Three-Penny Beaver which depicts the iconic animal in an oval frame and is the world's first stamp not to feature a monarch or the royal shield.

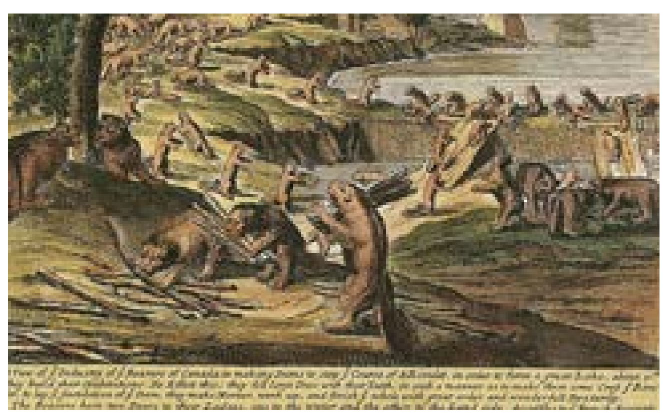
The stamp was designed by Sir Sandford Fleming, the famed Scottish-Canadian engineer, inventor, and a founding member of RCIScience. Since its publication, the beaver genome paper has been acknowledged for advancing sequencing technology, and has been ranked in the top 5% of all research outputs scored by Altmetric, as well as being the 11th highest scored article published in G3.

Looking ahead, Drs. Lok and Scherer are continuing to work towards reducing the cost of *de novo* sequencing. Although the cost of this method of sequencing was reduced to below $30,000, widespread use of *de novo* sequencing in clinical settings requires a much lower cost.

In addition to innovating for biomedical and clinical applications, Canada's Genomics Enterprise (CGEn)- a consortium including TCAG in Toronto, Michael Smith Genome Sciences Centre in Vancouver and the McGill University and Génome Québec Innovation Centre in Montreal recently announced an initiative project called CanSeq150, which invited researchers across the country to nominate the next 150 species that are important to Canada to have their genomes sequenced.

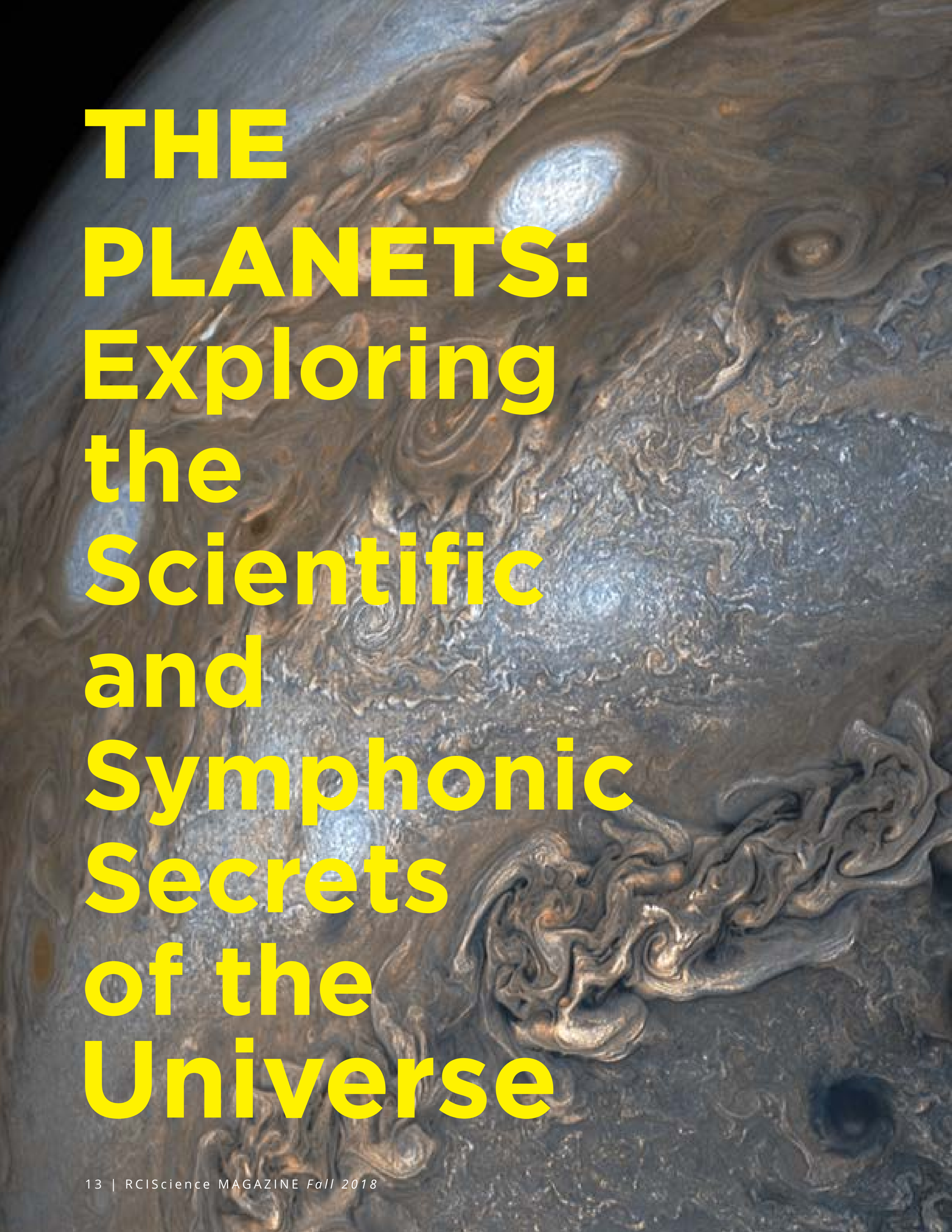
The program is expected to provide much needed insight into preserving biodiversity and improving conservation, in addition to contributing to our understanding of evolutionary biology and biomedicine. TCAG is leading this effort with the sequencing of the Canada Jay (*Perisoreus canadensis*), the Canada Lynx (*Lynx canadensis*) and its principal prey, the snowshoe hare (*Lepus americanus*).

Sequencing the beaver genome was made possible through the collaboration of five Canadian institutions: The Hospital for Sick Children, the University of Toronto, the Ontario Institute for Cancer Research, the Royal Ontario Museum, and the Toronto Zoo. The project was funded by Genome Canada, Ontario Genomics, Canadian Foundation for Innovation, the Government of Ontario, and the Lau Family Endowment for Genomics Science Development.



Beavers in the history of Canada were often depicted as industrious, building dams and houses. It is this trait, coupled with the connection to the beaver trade in early colonial Canada that enshrined the beaver in Canada's coat of arms. CREDIT: Wikimedia Commons

THE PLANETS: Exploring the Scientific and Symphonic Secrets of the Universe



Juno mission close-up of Jupiter's stormy clouds.
Credit: NASA/JPL-Caltech

What do music and planetary science have in common?

This intriguing theme attracted a full house of music and science lovers to a unique event co-presented by RCIScience and the Hart House Orchestra. The orchestra performed Gustav Holst's The Planets, a nod to the evocative beauty of the night skies from 100 years ago, while astronomers and planetary scientists gave snapshots of their research into our modern, scientific view of the solar system. For those of you who have never been to the Hart House Great Hall (I had not)—picture a Hogwarts-style room, complete with a dark timbered ceiling, enormous stained glass windows, bronze chandeliers, seventy-four stately shields and a gilded inscription wrapped around the entire perimeter. Adding to the event's palpable air of mystery, planetary images were projected onto a large screen in the middle of the hall, blocking our direct view of the 'Wizard of Oz'-esque orchestra that played behind.

By Alyssa Murdoch

Planetary geologist Dr. Sara Mazrouei studies the Moon. The Moon's surface acts as a time capsule, preserving everything from meteorite impact sites to Neil Armstrong's footprints. Sara uses thermal imagery from the Lunar Reconnaissance Orbiter, a spacecraft that has been active since 2009. Using these thermal lunar images, she is able to determine the age of crater impact sites based on their relative 'rockiness', with young craters being visibly 'rockier'. From there, she can determine the frequency of meteorite impacts over time, and whether there is evidence of change. Now, you may be wondering how useful it is to know how often the moon gets hit by space debris. As it turns out, very useful! For every meteorite that hits the moon, another twenty hit the earth. And following Sara's painstaking research, we now know that the impact rate has increased in the past 300 million years.

Dr. Alan Jackson's research is like cosmic detective work. He focuses mainly on giant celestial impacts: imagine massive objects soaring through space, colliding violently, leaving a cacophony of swirling debris in their wake. For an example close to home, recent theories suggest that the moon formed due to a giant impact on primitive Earth. The impact 'culprit' would have been about the size of Mars, ejecting chunks of our planet into its orbit and beyond. Other giant impacts may be responsible for a massive crater discovered at Mars' north pole, as well as for the unique iron-rich composition of Mercury. Dr. Jackson provided a compelling case for the integral role of giant impacts in forming and shaping our cosmic landscape.

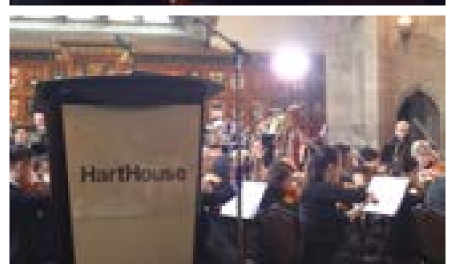
Dr. Matt Russo's work succinctly bridges the gap between planetary science and music. Dr. Russo wears many hats, including astrophysicist, science educator and musician. In exploring what makes music 'musical', he notes it is a mixture of mathematical ratios that happen to be pleasing to the ear. The mind-bending thing is that many of these ratios are naturally found in space: in the orbital patterns of distant solar systems, or within the light waves of Saturn's rings, and can therefore be transformed into otherworldly melodies for us to enjoy. Dr. Russo was inspired to merge his two passions when he first heard of TRAPPIST-1, a recently discovered solar system that harbours seven Earth-sized planets. While most media attention focused on TRAPPIST-1's potential for habitation, Dr. Russo was taken by an unusual feature of this new world – something called a resonant chain pattern. Simply put, as the planets orbit around the TRAPPIST-1 star, they move in almost perfect whole number ratios to each other and incidentally form the consonant mathematical ratios commonly found in music. Put to music, the movements of the TRAPPIST-1 planets sound melodious yet ethereal, not unlike many of the harmonies found in Holst's rendition of the outer world.

"While music and science may have some measurable, obvious overlap, it is hard to ignore the feeling that there may be something deeper, something more elusive about their relationship."

It is easy to understand why astronomy is one of the oldest sciences, practiced worldwide. We have a universal reverence for the stars that can be felt deeply on a clear night, away from the city lights. Despite the major advances made by modern astrophysics, the cosmos remains the ultimate unknown frontier, inspiring a wide range of human emotions from wonder to beauty to fear.

The Planets beautifully captures this range, highlighting our timeless desire to ponder the outer world and our place within it. While music and science may have some measurable, obvious overlap, it is hard to ignore the feeling that there may be something deeper, something more elusive about

A packed house in the Hogwarts-like Hart House Great Hall at the University of Toronto. The large screen showing planet images partially conceals the orchestra behind. CREDIT: Kirsten Vanstone



Left to right: Dr. Sara Mazrouei, Dr. Alan Jackson, Dr. Matt Russo, our scientists who explored cratering, impacts and the connection between orbital resonances and music. CREDIT: Sandhya Mylabathula

their relationship. As I left Hart House that day, I was reminded how there are some experiences so indescribable in this world, that perhaps our best hope in expressing them is through another, equally unexplainable phenomenon.

The Planets: A Musical Odyssey of Evolution, Environment and Exploration, was presented in partnership with the Hart House Orchestra in October, 2017. Many thanks to Dr. Matt Russo, Dr. Alan Jackson and Dr. Sara Mazrouei, our speakers. Special thanks to the Hart House Orchestra Musical Director & Principal Conductor, Henry Janzen, to Dr. Peter Martin, violinist and Chair of the University of Toronto Department of Astronomy, and to Zoe Dille and the Warden and staff of Hart House.

THE SPINNING MAGNET

Interviewing acclaimed author Alanna Mitchell

By Jon Farrow

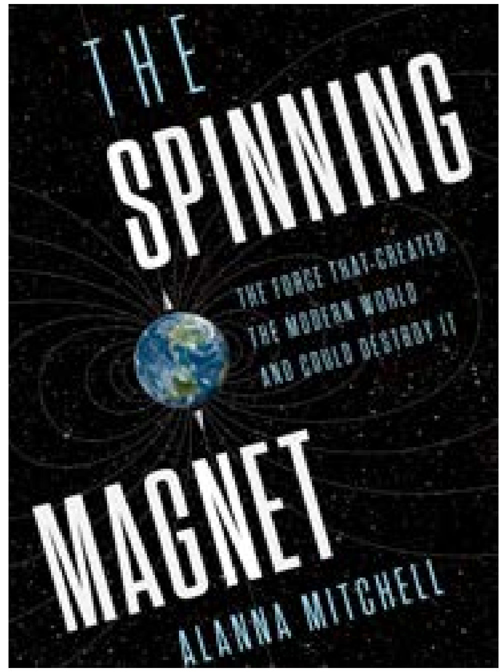
"How do you put all those pieces together and discard the ones that are wrong?"

The world as we know it isn't ending. Maybe.

I sat down with Alanna Mitchell, author of a new popular science book about geomagnetism, who spoke at an RCITalk in February. We discussed the Earth's core, globetrotting adventures, and the potentially imminent end of modern civilisation: normal weekday topics for a science writer!

It's been a long time since I've read a popular science book that combines such a colourful cast of characters with such a powerful sense of narrative. In The Spinning Magnet, Alanna Mitchell invites us on her journey of discovery, through winding roads in France to geochemistry conferences, historical archives and the quantum world, all to find out what's happening below our feet. What does it mean to live on a giant magnet? Have the poles reversed before? How do we know? Will they do it again?

When I caught up with Alanna in a coffee shop on the Danforth, she was every bit the science writer once known in some circles as the Globe and Mail's Armageddon reporter: inquisitive, well-spoken and generous. She was somehow both measured and excited in her responses,



Alanna Mitchell speaks at the Waterloo Public Library about her book, The Spinning Magnet. It is published in Canada by Viking Press.

enthusiastically telling me about the people she met and the things she found out, but always careful not to overstate what there was not evidence for. I can see how she has made a career in writing about difficult, sometimes uncertain (but always important) science stories. Her other major book, *Sea Sick*, deals with the implications of increasing atmospheric carbon dioxide for the oceans.

This magnetic journey all started for Mitchell with research for a different book about the Franklin expedition to find the Northwest Passage. She found out about the 19th-century obsession with measuring the strength of the magnetic field, known as the Magnetic Crusade, and was hooked.

"I was fascinated by how much I didn't know when I started researching. And about how much they didn't know at that time. How do you build up this body of knowledge? How do you put all those pieces together and discard the ones that are wrong?"

The Spinning Magnet is the story of Alanna chasing down those questions and bringing you along for the ride. The pace of the book is furious, flitting from trips through the French countryside to find the very seam of terracotta that "changed the course of science" to a Maryland lab with a "great hazardous spinning sphere of sodium". We meet charismatic guides like Jacques Kornprobst, the man on a mission to resurrect the reputation of a geologist named Brunhes and Frank James, the walrus-mustachioed professor who literally wrote the book on Michael Faraday.

You get to understand not just that the Earth is a magnet with volatile poles, but why and how we know. Mitchell also won't let you forget that a pole reversal might have serious consequences. She discusses the potential impact on the natural world and our modern way of life. Every chapter has you coming back to the question: Is the end of the world around the corner? I put that question to Mitchell.

"No, the world is not ending. What may be happening is that the direction of the Earth's magnetic field might be changing. And that's unclear. Nobody can tell for sure. We can only predict it 5 years in advance, and even that is an incredible feat of mathematics."

So there's probably no need to start preparing for Armageddon. But it can't hurt to read the book to find out for yourself.

Jon Farrow is a science writer in Toronto. After nearly 4 years training and working in science communication in the UK, he's back home and excited to inspire and enthuse the world with science. You can read more of his work at jon-farrow.com

THE SCIENCE OF

Sparkling Wine

By HAMZA BIN TAUFIQUE and SWAPNA MYLABATHULA

Credit: Rawpixel/Unsplash

THE FIZZ CLUB

There is an increasing interest in sparkling wine across Canada, with marked growth in production in Ontario, British Columbia, Nova Scotia and Quebec. More than ever, winemakers are searching for information about how each of the many stages of winemaking affects the final product. In an initiative called The Fizz Club, winemakers and scientists exchange ideas about all stages of sparkling winemaking. Yes, there's a lot of artistry in winemaking, but it turns out, there is a lot of science as well!

SPARKLING WINE CHEMISTRY

There are many approaches to producing sparkling wine, with each method impacting the flavour profile, as well as the size of the bubbles, foam and many other characteristics.

Sparkling wine differs from other wines in that it contains higher levels of carbon dioxide. This CO2 produces the bubbles that give sparkling wine its effervescent, fizzy quality. The carbon dioxide is most often produced during a second fermentation, which can take place either in a tank or within the individual bottle, depending on the winery's process.

The bubbles in sparkling wine do not last as long as their counterparts in beer, but the foam, the mass of bubbles at the top of the glass, is a key component in sparkling wine. Sparkling wine produces what is called a wet foam that rises and falls quickly. Beer foam, on the other hand, produces a creamy head that sticks around a lot longer. In foam, proteins and polysaccharides/glycoproteins (proteins with sugars attached to them), form a membrane around the bubbles.

Many compounds influence the height and stability of sparkling wine foam. Proteins and polysaccharides form a double layered film around each bubble, strengthening it and providing stability. These same proteins can make still wines appear hazy and are usually removed from table wines. Bentonite, a positively-charged clay compound, is often used in still wines to attract and remove the negatively charged proteins, although some natural wines are left cloudy.

Other compounds that influence foam include ethanol, lipids, various acids and tannins. If the ethanol level is too high, the bubbles disappear. The presence of fatty acids and lipids can negatively affect the foam. Lactic acid bolsters foam stability while malic acid increases height. Tannins can bind with proteins, weakening the foam and adding a bitter taste. Making a good sparkling wine is a chemical balancing act!

Because bubbles play such an important role in sparkling wine, minimising bubble loss is important. Bubble loss can happen during winemaking, but a more familiar way to lose them is through gushing, the speedy release of foam upon opening a bottle. Gushing can be caused by excess pressure, defects in the glass, or other chemical compositional factors.

For sparkling wine, a little dust is OK.

For ideal flavour and foam, timing the grape harvest is critical. As a grape ripens, its sugar content increases while it's acid content drops. If the acid is too low at the time of picking, the wine will lack body, complexity and the ability to age. Generally, grapes picked too late can produce wine with a foam that tends to disappear quickly.

Once harvested, grapes destined for sparkling wine are gently pressed in bunches with their stems intact. Gentle pressing is key because the harder and longer the pressing, the more unwanted phenolic compounds, such as anthocyanins are released.

Pressings release juice in different phases called fractions. For sparkling wine, the juice obtained from the first fraction is best since it contains the fewest undesirable compounds. However, second and third fractions can still be used in blending, or sold to distilleries.

Using chemistry, Dr. Kemp busted some wine myths. For example, many assume that smaller bubbles mean a better quality sparkling wine. In fact, smaller bubbles can indicate that there is higher pressure in the bottle but the type of glass used for sparkling wine can also have an effect. As these bubbles ascend, they get bigger and chains of bubbles can be seen moving up the glass.

Another myth is that you should keep your glassware spotlessly clean. In fact, for sparkling wine, a little dust is OK. Bubble formation requires nucleation sites or gas pockets where bubbles are able to form. Nucleation sites include imperfections in the glass surface or small amounts of dust or other particles. Dr. Kemp recommended that sparkling wine glasses only be rinsed with water and never washed with detergent.

Winemaking is definitely an art, but as Dr. Kemp and her colleagues show, research can help winemakers improve their product. The science of sparkling wine is multidisciplinary—it includes chemical analysis in a lab, plant biology, soil and water science, microbiology and sensory science. It also engages many stakeholders, including scientists and winemakers such as those brought together by The Fizz Club.

Together, these experts have created a beverage that helps people celebrate special occasions, including at our Science of Sparkling Wine talk. So next time you indulge in some bubbly, think of all of the science going on in your glass!

Dr. Belinda Kemp tells stories of science in the vinyard. CREDIT: Horst Herget

Author Hamza bin Taufique at the Science of Sparkling Wine event. CREDIT: Horst Herget

VINO-LINGO

Viticulture: The science of grape growing. From the Latin, *Vitis*, meaning vine.

Oenology (e-nol-ogy): The study of wine. From the Greek, *Oinos*, meaning wine.

Cool climate oenology: The study of wines grown in cooler climates like that found in Southern Ontario. According to the Wine Council of Ontario, grapes grown in cooler climates ripen slowly, accumulating flavour over a longer period, resulting in a higher acidity and more mineral flavours. In warmer regions, grapes ripen quickly, producing higher sugar levels and lower acidity.

Sparkling wine: A generic term for a wine that contains carbon dioxide. There are many methods of production, each generating a unique product. Examples include Champagne, Prosecco, Cava, and Crémant d'Alsace.

HOW TO BECOME A WINE SCIENTIST

Originally hailing from Brighton, England, Belinda started out as a trained dancer, working for various theatres and circuses. After realising she didn't possess the requisite skills to live out her fantasy of driving a tractor through the vineyards of Barcelona, Dr. Kemp turned her hand to viticulture and oenology research.

As she put it, "I thought I would be doing an awful lot of wine tasting, but soon realized that the undergraduate program involved a lot of plant science and chemistry, which I ended up liking a lot." Internships took her to wineries all over the world. She eventually pursued a PhD at Lincoln University's Centre for Viticulture and Oenology in New Zealand, where she studied tannin, fruity and green aromas, and sensory characteristics of Pinot Noir wine.

In July 2013, Dr. Kemp became a Senior Scientist in Oenology at Brock University. "I saw a job opening in Canada at Brock, applied for it, and then was interviewed over Skype for 3 to 4 hours while sitting at my kitchen table."

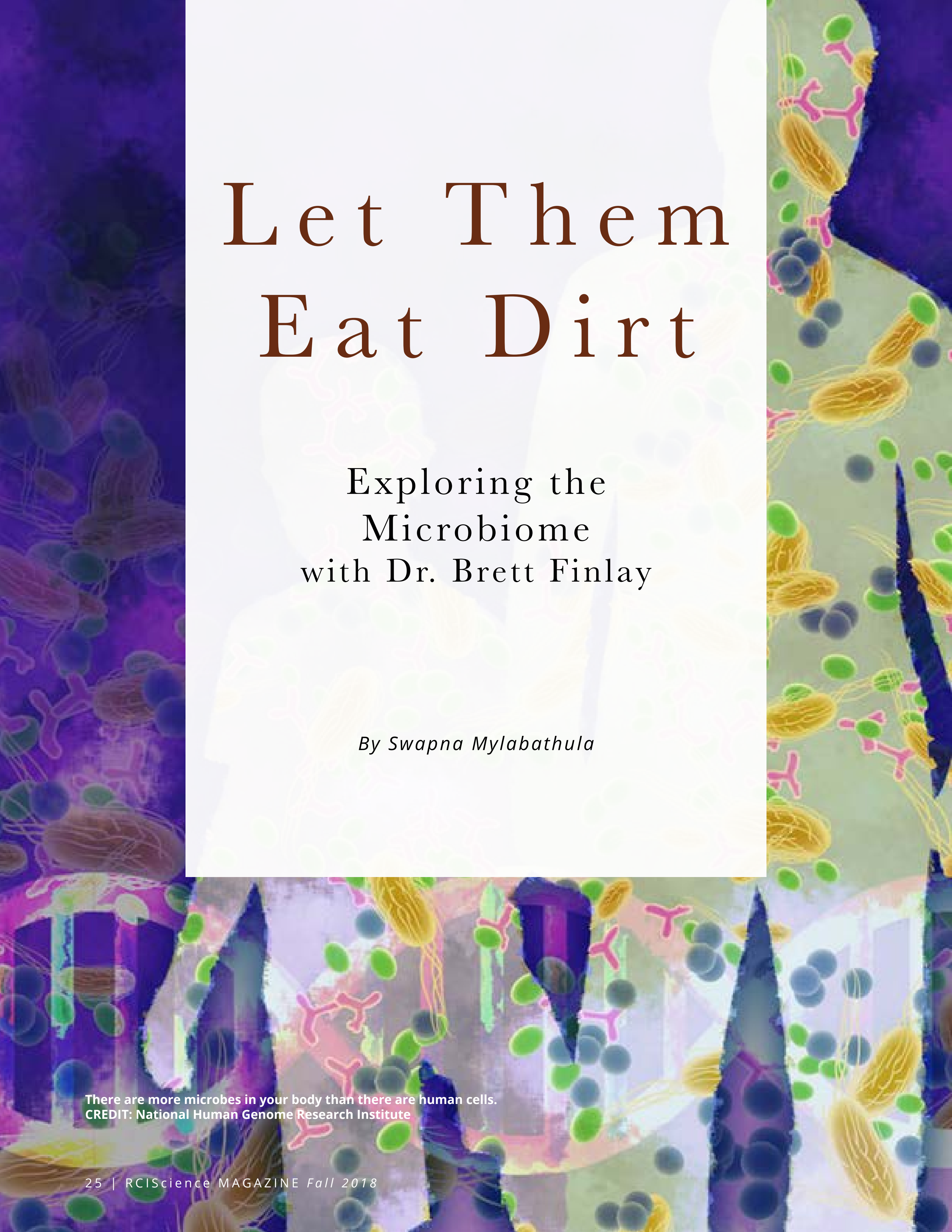
After moving to Canada, Belinda had an experience familiar to many immigrants. "I didn't realize how cold it gets in Canada. I was not prepared for it!" A practical demonstration of why Brock is the perfect location for the Cool Climate Oenology and Viticulture Institute (CCOVI).

Dr. Kemp's role at CCOVI is 50% scientific research and 50% outreach for the wine industry. Her research supports the needs of commercial Ontario wineries and focuses mostly on the flavour chemistry of sparkling wine as well as on red wine tannins. A large part of her outreach role involves transferring her research findings back to the commercial wineries but she also engages the local community in public talks.

Let Them Eat Dirt

Exploring the Microbiome with Dr. Brett Finlay

By Swapna Mylabathula



There are more microbes in your body than there are human cells.
CREDIT: National Human Genome Research Institute

Have you ever used the "5 second rule", where food that has fallen on the floor is safe to eat if it's only been there for 5 seconds or less? To put it more scientifically, according to this convention, 5 seconds is not long enough for the food to reach an unacceptable level of contamination.

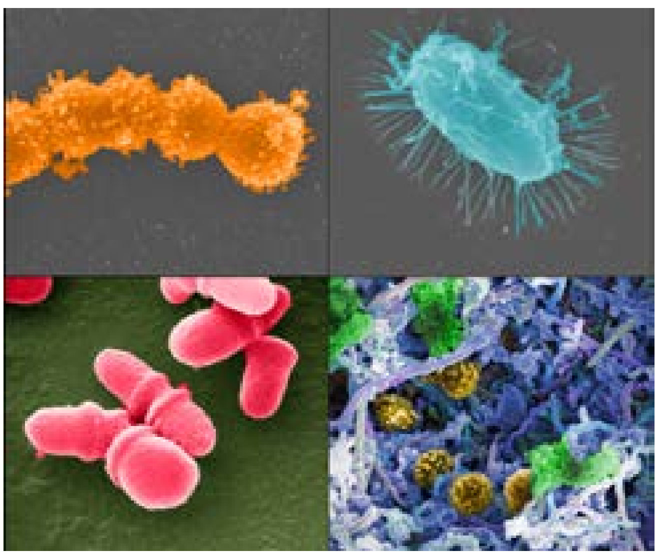
Upon examination by science, it turns out that time is much less of a factor than the surfaces involved. On sticky, gummy surfaces, contamination happened much more quickly than on dry ones. So it's more like a zero-second rule on a wet surface, and a many-second rule on a dry one.

But what would happen if we just ignored all of this and simply ate the germ-laden food? Do we need to avoid contact with microbes in the subway? Should a child be allowed to play in the dirt? Dr. Brett Finlay is a world-renowned microbiologist, professor at the University of British Columbia and recipient of the Order of Canada, whose research considers what would happen if we learned to embrace the germs in our environment.

The microbiome is the word used to describe the multitude of microbes that make up our bodies. Studying the microbiome, as Dr. Finlay does, reveals that a diversity of microbes is actually beneficial to us. Further, our over-sanitized environment may have thrown our microbiomes off kilter.

Hundreds of years ago, microbes were first described by Antoni van Leeuwenhoek, laying the foundations for the field of microbiology. Later, it was recognized that microbes caused infectious diseases, including deadly cholera. It was cholera in particular that led to the important idea that removing germs from the environment could save lives.

Large-scale sanitization practices like sewage-removal and regular garbage collection were two major efforts to eliminate disease-causing germs. Then antibiotics came on the scene to rid us of more disease-causing bacteria. Vaccinations fortified our bodies against the viruses that cause infectious diseases such as measles, mumps and tuberculosis. Overall, along with handwashing, wipes and sanitizing cleaners, it has been a very successful process.



Microbes are everywhere and they are not all the same.
CREDIT: National Human Genome Research Institute

On the other hand, we have seen an increase in non-infectious diseases. Dr. Finlay explains, “In the last 50-years, pick almost any infectious disease and the rates have gone down. We don’t have the polio and smallpox that we used to have. And that’s great! So this is a really lovely success story. But where the plot thickens is when you consider non-infectious diseases like asthma, diabetes, Crohn’s Disease, Multiple Sclerosis, Autism, Attention Deficit Hyperactivity Disorder, Obesity, you name it! So when you look around our world today, we see these kind of diseases. So what’s happened to make this change?”

Dr. Finlay’s research points to the idea that we have gotten too clean, changing the microbes around us and affecting the diseases we see in the modern world.

The top ten causes of death as listed by the U.S. Centers for Disease Control are now all linked to the microbiome except for one: accidents. Can we target microbes to treat these diseases? In his lab, Dr. Finlay has shown some ways how this might work.

Our microbiome is established before birth. It starts impacting our health at that time and continues to evolve through all stages of life. Dr. Finlay demonstrated the role of microbes in a critical window early in life. An absence of microbes in early life results in the development of asthma in both mouse models and human children, illustrating the possibility that the presence of certain microbes early in life can influence whether asthma presents later on.

He has also done extensive work exploring the influence of microbes in disease involving Salmonella and E. coli and has even created a vaccine for cows to prevent the spread of E. coli to humans through feces, contaminated water and undercooked beef.

The field of microbiology is ripe with opportunity to explore how large of an impact something so small can have on human lives. Small, but numerous! The number of microbial cells in a human body outnumbers the number of human cells.

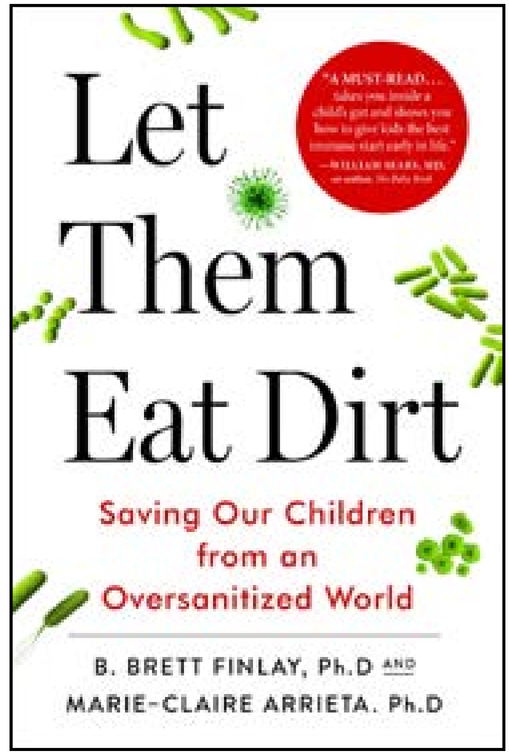
And our microbiomes are unique, varying drastically from one person to the next. Even on one body, the microbes on the right hand are different from those on the left. At best, our microbes are 50% similar to our neighbour’s, making the microbiome a particularly intriguing target for personalized medicine.

The microbiome affects development and function, including the brain, gut and immune system. Some studies reveal that transferring microbes from depressed, anxious or stressed mice into healthy mice results in the healthy mice becoming depressed, anxious and stressed.

Beyond health and disease, a focus on the microbiome may also be of use in another realm—performance enhancement in sport. Microbes affect our circadian rhythms, bone density and tendency towards inflammation, all factors important to athletes. Perhaps the future holds a shift from doping with drugs to doping with bugs!

So if microbes are the cause of disease, but can also help us maintain health, what should we do? Dr. Finlay's answer is to find the balance between disease prevention and a healthy exposure to microbes in our environment. Currently, we've tipped the balance toward oversanitization in the developed world, and as a result, we are seeing an increase in non-infectious diseases.

Dr. Finlay wants to bust the myth that cleaner is better and encourages us to find a microbe balance. While we should certainly continue to wash our hands for disease prevention, we can relax regarding microbes in other aspects of daily life. The bottom line is that children are mud magnets and this helps them manage their microbes for better health. So, let them eat dirt!



Cover of *Let Them Eat Dirt*, published in 2016 by Greystone Books.


Letting kids get dirty may be key to boosting their immune systems. CREDIT: Jordan Rowland, Unsplash

Citizen Science & Social Action

By Jenessa Doherty

Dr. Ashley Rose Mehlenbacher, Assistant Professor of English, University of Waterloo

The world is full of complex problems. From climate change to galaxy formation, we often look to science to make sense of the world and answer important questions that help solve past problems or influence future behaviours. We trust experts to analyze data and identify patterns that will answer complex questions. Once discovered, we expect these findings to be shared in an accurate, reproducible, and measurable way.

But who are today's science experts? And as the landscape of sharing information changes, do we really trust experts anymore? Or is it simply that the growth and speed of information sharing makes us think we're all experts? These are the questions asked by Dr. Ashley Rose Mehlenbacher, Assistant Professor at the University of Waterloo, specialising in rhetorical theory.

The reality, argues Dr. Mehlenbacher, is that the 21st century is replete with issues and problems that require different people to come together to identify creative solutions. In addition to the multidisciplinary science teams and experts that we have come to expect, we now have new groups of non-experts contributing to the discovery of these solutions. But how do we build trust in these non-experts and what roles do they, or should they, play in the dissemination of scientific knowledge? To answer this, we must first determine the definition of "expert".

THE MAKING OF AN EXPERT

Traditionally, an expert was considered someone who held an accreditation of some sort or who was formally educated or trained. In the age of the internet, however, this definition has evolved to include individuals who are informed and have acquired expertise without accreditation or formal training.

The traditional markers of an "expert" no longer guarantee more expertise than a "non-expert". Dr. Mehlenbacher contends that the shift in the concept of "expert" is apparent through changes in our communications, which have enabled us to question traditional experts and have redefined how we measure and monitor expertise.

This has, in part, led to a changing culture of trust in scientists. There is a growing doubt in experts and whether they have the best interests of the public at heart. This is evidenced by the anti-vaccine movement and the strategic introduction of new words into our vernacular such as "post-truth". These changes are explored in books like The Death of Expertise or Are We All Experts Now?

Dr. Mehlenbacher reasons that, as we rethink expertise, citizen science can help increase trust in experts. The term citizen science is used to describe public participation in scientific research. By immersing everyone in science and making the scientific method more accessible, citizen science can help assuage the growing skepticism of science as a knowledge-making practice. Citizen science can also help address concerns over information blackouts following techno-scientific disasters, such as the Gulf Oil spill, where corporations or governments do not make the full extent of information available.

CITIZEN SCIENCE

Citizen science, Dr. Mehlenbacher explains, is a way to empower everyday people to get involved with finding creative and civically-empowered solutions to problems. Mobilizing the general population to help with research makes tasks like large data collection and analysis easier, faster, and more robust.

Dr. Mehlenbacher describes the two types of citizen science. The first is a top-down process, in which a scientist sets up a project and solicits help from volunteers in the general population, who become the citizen scientists. An example is Foldit, a game that enables citizen scientists to work online to determine the different ways proteins can be folded. This increases our overall knowledge and understanding of the protein folding process, while engaging non-researchers in the subject.

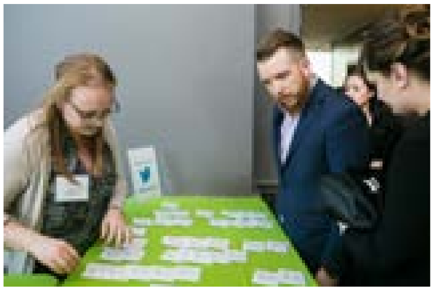
Another example, Fukushima InFORM, is a network that asks citizen scientists to collect and assess data and identify radiological risks to Canada's coastal regions. This is an example of the second type of citizen science: bottom-up. These are often grassroots movements in which citizen scientists identify important areas of research, develop their own research projects, then collect and analyze data outside of academia.

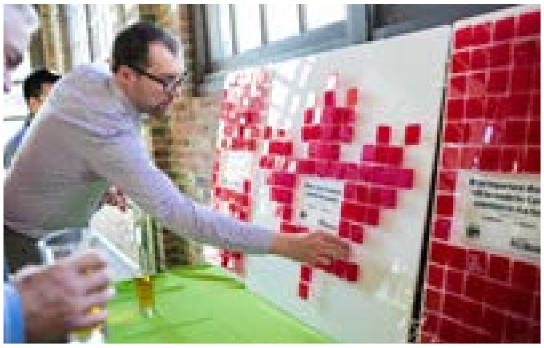
Other examples include Safecast, an independent research group that collects, shares and helps the public understand radiation contamination data, and Public Lab, which builds tools and innovative methods for environmental monitoring.

The opportunities for citizen scientists continue to grow. Dr. Mehlenbacher identifies that, although science itself is an important process, citizen science enables that process to be understood, challenged and improved by a much larger group of people.

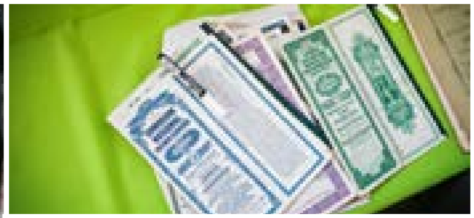
Ultimately, she argues, we need both traditional experts and citizen scientists to solve the complex problems of the world in fair, equitable, and civically engaged ways.

For more information on citizen science projects you can get involved with, visit www.scistarter.com or connect with Dr. Ashley Rose Mehlenbacher at arkelly@uwaterloo.ca.



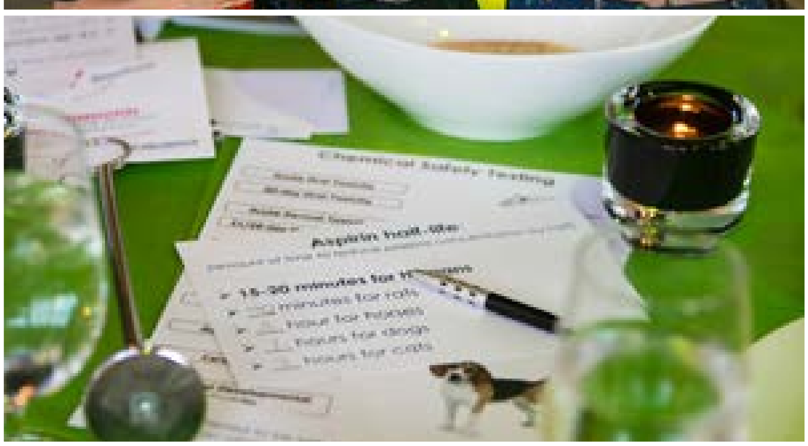


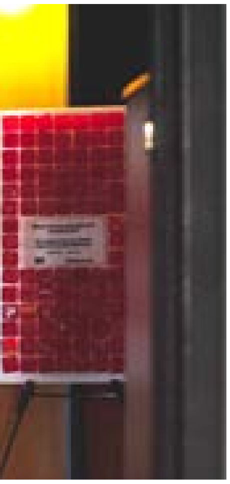

Science
Roundhouse

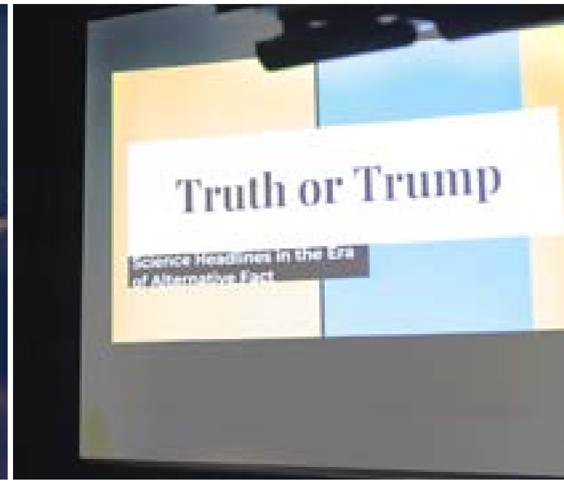









Chemical Safety Testing
Aspirin half-life




Truth or Trump
Science Headlines in the Era of Alternative Fact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2018 Financial Report

ROYAL CANADIAN INSTITUTE
Balance Sheet

As at	June 30 2018	February 28 2017
Assets		
Current		
Cash	$ 2,706	$ 21,988
Accounts receivable	15,000	9,834
Prepaid expenses	4,280	9,279
	21,986	41,101
Investments (note 3)	1,505,457	1,547,757
Portraits	3,200	3,200
	$ 1,530,643	$ 1,592,058
Liabilities		
Current		
Accounts payable and accrued liabilities (note 4)	$ 47,897	$ 20,758
Deferred revenue (note 5)	23,050	30,000
	70,947	50,758
Net Assets (note 6)		
Unrestricted	1,447,696	1,531,300
Internally restricted	12,000	10,000
	1,459,696	1,541,300
	$ 1,530,643	$ 1,592,058

See accompanying notes to financial statements.

On behalf of the Board of Trustees

K. W. Yoon Trustee

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ROYAL CANADIAN INSTITUTE

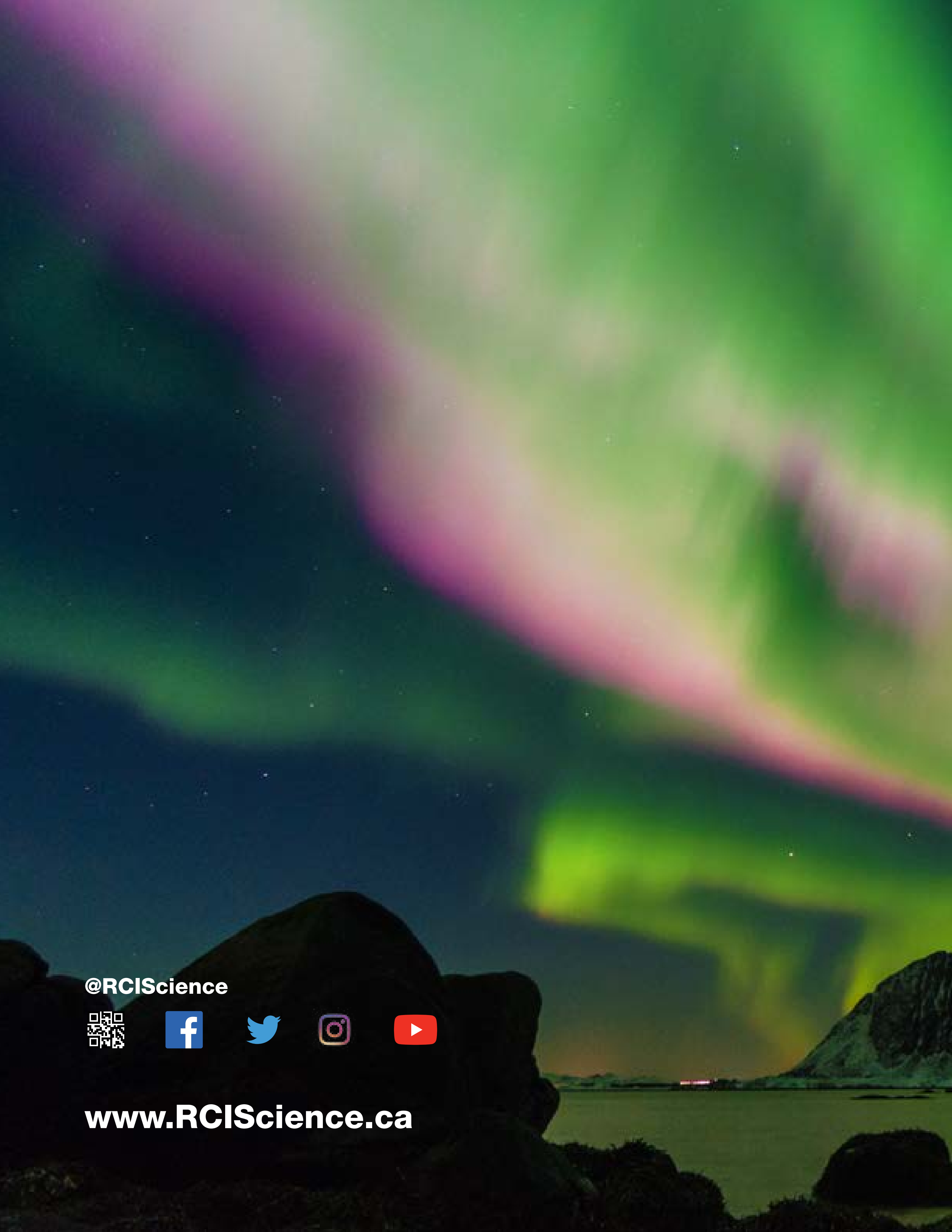
Statement of Revenue and Expenses and Changes in Net Assets

	For the period March 1, 2017 to June 30, 2018	Year ended February 28, 2017
Revenue		
Fundraising events	$ 94,950	$ 77,800
Investment income	62,791	44,831
Donations	42,182	27,755
NSERC grant revenue	8,550	-
Membership fees	5,898	7,754
	214,371	158,140
Expenses		
Staffing costs	136,478	102,839
Fundraising events	77,165	46,354
Lecture series	48,812	21,214
Investment management fees	14,129	11,030
Insurance	10,099	7,704
Webcasting	9,854	7,618
Professional fees	9,355	7,790
Office expense	9,201	8,861
Annual general meeting and council	4,575	6,549
Space rental	2,975	2,047
Science Scholarship	1,000	6,000
	323,643	228,006
(Deficiency) of revenue over expenses before other item	(109,272)	(69,866)
Other item		
Unrealized gain on investments	27,668	175,400
Excess (deficiency) of revenue over expenses for the year	(81,604)	105,534
Net assets, beginning of year	1,541,300	1,435,766
Net assets, end of year	$ 1,459,696	$ 1,541,300

ROYAL CANADIAN INSTITUTE

Statement of Cash Flows

	For the period March 1, 2017 to June 30, 2018	Year ended February 28, 2017
Cash provided (used) by operating activities		
Excess(deficiency) of revenue over expenses for the year	$ (81,604)	$ 105,534
Charges not requiring a current cash payment		
Loss on sale of investments (net)	8,464	6,203
Unrealized gain on investments	(27,668)	(175,400)
	(100,808)	(63,663)
Changes in non-cash working capital components		
Accounts receivable	(5,166)	2,115
Prepaid expenses	4,999	113
Accounts payable and accrued liabilities	27,139	(2,623)
Deferred revenue	(6,950)	5,000
	20,022	4,605
Cash (used) by operating activities	(80,786)	(59,058)
Cash provided (used) by investing activities		
Purchase of long-term investments	(629,618)	(44,755)
Proceeds on disposal of long-term investments	691,122	118,997
Cash provided by investing activities	61,504	74,242
Increase (decrease) in cash during the year	(19,282)	15,184
Cash, beginning of year	21,988	6,804
Cash, end of year	$ 2,706	$ 21,988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