UK Research and Innovation

The impact of UK-Canada research collaboration

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Foreword

It's no secret that Canada and the United Kingdom share a noteworthy history of collaboration when it comes to research and innovation: the UK is Canada's second most frequent collaborator worldwide. The case studies in this brochure embody the tradition of UK-Canada collaboration while also highlighting the bright future between our two countries. Between 2013 and 2018, UK research collaboration with Canada jumped 40 percent, making Canada the UK's ninth most frequent collaborator. You'll find as you read on that researchers in the UK and Canada have together made strides in addressing everything from infertility, to data privacy, to air pollution in microenvironments. These remarkable examples prove what we already know: global collaboration is necessary for building a brighter, more sustainable, more equitable future.

As the UK's primary public funder of research, UK Research and Innovation (UKRI) aims to create an environment in which international collaboration flourishes. Big challenges demand big thinkers - those who can unlock the answers and further our understanding of the important issues of our time. Our role is to bring together people who can innovate and change the world for the better and to create knowledge with impact, which requires a global reach. All of the research projects described in this brochure have received support from UKRI. In many cases, support has come from funders in Canada, including the Natural Sciences and Engineering Research Council of Canada and the Social Sciences and Humanities Research Council of Canada, complementing UKRI's funding.

UKRI's partnership with stakeholders in Canada is ever-growing and I am delighted to introduce a new phase in UKRI's presence in the region: the transition of the UKRI USA Office to the UKRI North America Office to cover Canada as well as the United States. The case studies in this brochure reflect the enduring commitment to collaboration between UKRI and Canadian research funders: a relationship I am pleased to continue building as we cultivate research excellence together.

Chloë Somers
Director, UK Research and Innovation, North America Office

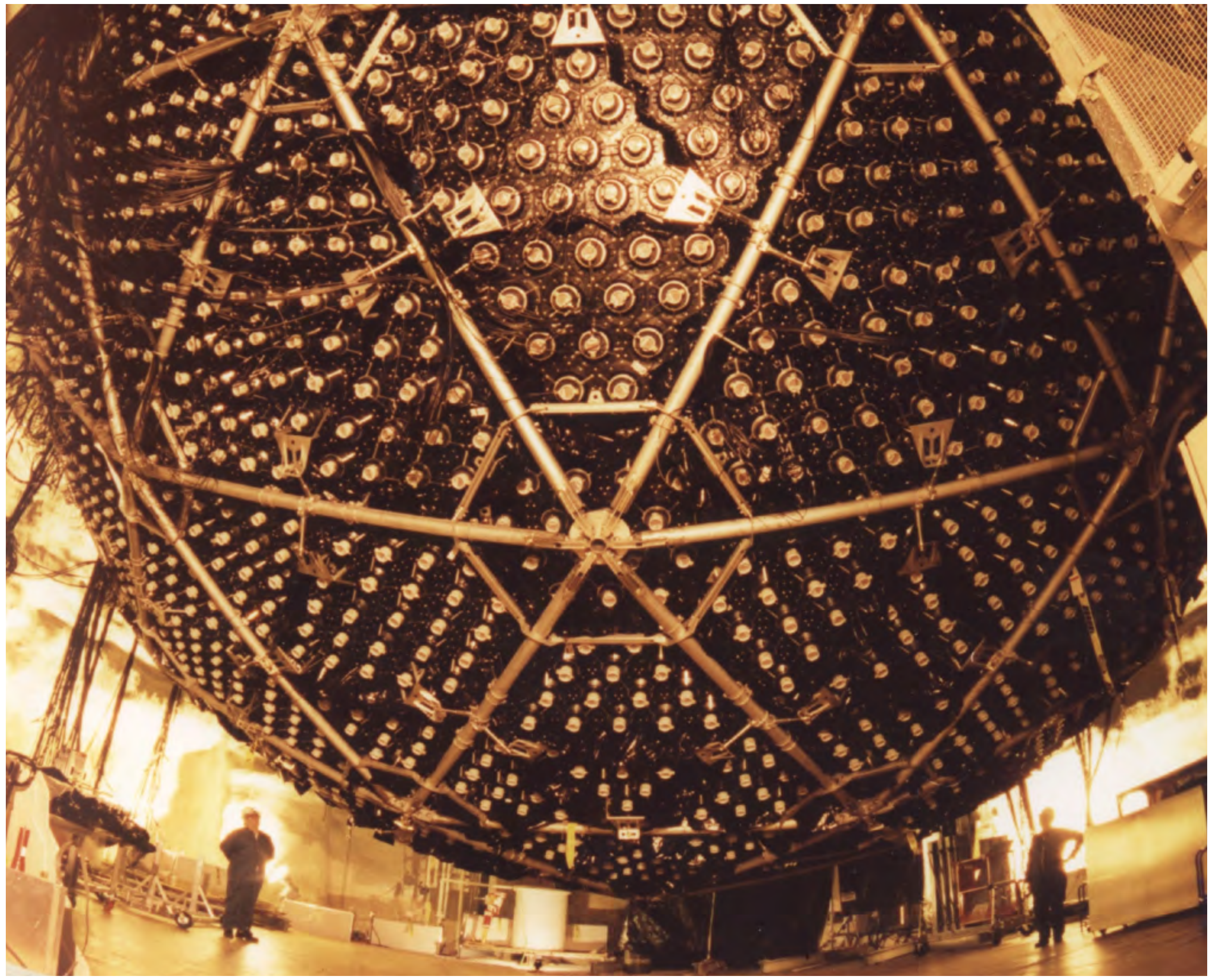
> **It's a great example of how sharing your research increases its impact.**

> **Why not work together? We get along great...she makes work fun...and two heads are better than one.**

> **It's just been a huge and really positive collaboration between our two nations.**

How Neutrinos – the Ghosts of Particle Physics – Change Identities

Findings earned researchers the 2015 Nobel Prize in Physics



The Sudbury Neutrino Observatory — located in a mine in Ontario, Canada — was designed to detect solar neutrinos through their interactions with heavy water. Researchers spent decades conducting experiments at the observatory in an effort to understand the true nature of neutrinos.

Image courtesy of SNO

In the late 1960s, astrophysicists Raymond Davis and John Bahcall began studying neutrinos emitted by the sun. Neutrinos are fundamental particles — much like electrons — but without an electric charge and with very little mass. This means they don't interact much at all with surrounding particles and, as a consequence, don't make up the matter that we see around us.

Because of these weak interactions, neutrinos produced during nuclear reactions in the core of the sun go straight through the dense material of the sun like light through the clearest glass. As a result, Davis and Bahcall figured that by observing these escaping solar neutrinos, they could observe solar nuclear reactions taking place in real time.

Unfortunately, during their observations, the researchers only found a quarter to a third of the number of neutrinos that they had expected to see. This case of the missing neutrinos came to be called the "solar neutrino problem" and potential solutions included finding fault with the experiment and questioning our understanding of the sun's core.

"There was a third possibility though, which was that we don't understand neutrinos and that in fact they can change," says David Wark, Professor of Experimental Particle Physics at the University of Oxford.

In the Standard Model of Particle Physics, there are believed to be three flavours of neutrinos — electron, muon, and tau — and they are described based on their weak interactions. So, for example, an electron neutrino when it interacts weakly makes an electron, a muon neutrino when it interacts weakly makes the electron's heavier cousin, the muon, and a tau neutrino when it interacts weakly makes the electron's still heavier cousin the tau. What's more, the Standard Model notes that because these neutrinos are massless the only way to truly look at them is through these interactions.

But in the 1998, Japanese physicist Takaaki Kajita reported that data from neutrinos created by cosmic rays hitting our atmosphere were changing identities or "oscillating" on their way to the Super Kamiokande detector in Japan. This meant that an electron neutrino, for example, could change into a muon neutrino along the way or a muon neutrino could change into a tau neutrino and vice versa.

Meanwhile in Canada, physicist Arthur McDonald led an effort, which showed that solar neutrinos weren't simply disappearing along the way but were also changing their identity on their way to Canada's Sudbury Neutrino Observatory. This would explain why Davis and Bahcall, who were only looking for electron neutrinos in their experiment, weren't detecting other neutrinos that had likely changed their identities along the way.

> **"Nobody wants to confirm a theory. That's dead boring."**

In fact, the Sudbury Neutrino Observatory located, close to 7,000 feet under ground in a mine near Ontario, was able to detect not only electron neutrinos but neutrinos in other forms, too, using 1,000 tons of heavy water that served as a target for solar neutrinos. Wark joined the Canadian pioneers at SNO in the 1980s and was an early member of what became an international team of researchers who spent more than three decades working on the solar neutrino problem. "It was a really, really hard experiment," he says. "And I have nothing but boundless gratitude for the Canadian government remaining patient with us as it took many years longer than it was supposed to. They kept faith with us and they kept us funded and eventually it worked."

In 2015, Takaaki Kajita and Arthur McDonald received a joint Nobel Prize for their experiments that showed neutrinos changed identities, which also proved that they did indeed have mass, however small.

"The stereotype of scientists is that you go out and you want to confirm your theory," says Wark, adding that nothing could be further from the truth. "Nobody wants to confirm a theory. That's dead boring. And so here is the first time that somebody has found something where the Standard Model of Particle Physics gets it wrong."

Wark is also part of the Tokai to Kamioka or T2K experiment, which built on the theory of neutrino oscillations. The question here related to whether neutrinos and antineutrinos oscillated in the same way and, as part of the experiment, researchers sent intense beams of muon neutrinos from Tokai on the east coast of Japan across to Kamioka, which is close to 300 kilometers (roughly 190 miles) away, in western Japan. "The Standard Model of Particle Physics starting from the Big Bang would produce roughly equal quantities of matter and antimatter," says Wark. "And so there must be some law of physics that distinguishes matter from antimatter, and neutrino oscillations could be a clue to that."

Both the SNO and T2K experiments received the 2015 Breakthrough Prize for Fundamental Physics.

This research was supported in part by UK Research and Innovation's Science and Technology Facilities Council and the Canadian Government.

A More Precise Way to Predict the Weather

The moving mesh method allows researchers to focus on specific regions of the world

When it comes to developing a weather forecast, meteorologists must not only make sure their predictions are precise and accurate, but they also have to make them quickly.
"The joke is you don't want to take more than 24 hours to give you tomorrow's forecast," says Chris Budd, a professor of applied mathematics at the University of Bath.

For decades, researchers have relied on computational methods that involve dividing up the earth into a large number of small regions. They then solve mathematical equations, referred to as Navier Stokes equations, for the weather in each of those small regions and combine the results from each region to obtain a weather forecast for the entire planet. A computational mesh — named for its resemblance to a fishing net or mesh enveloping the globe — is the way in which the regions are arranged or divided.

"In general, the smaller the regions are or, in other words, the larger the number of points in the computational mesh, the more accurate the calculation," says Budd. "But, at the same time, the longer the calculation takes."

As a potential solution, in the 1990s, Budd began collaborating with Robert (Bob) Russell, a professor of mathematics at Simon Fraser University's Vancouver campus, to make the mesh more concentrated and, in the process, focus on regions that are experiencing significant changes in weather. To do that, researchers bring the mesh points closer together in those areas and allow them to be more spread out in areas where not much is happening.

So, for example, if there's a storm brewing over the Bahamas, researchers would make the cells of the mesh over that region smaller — say, a kilometer apart — allowing them to make more precise predictions.
At the same time, if there isn't much activity over the North Atlantic, the cells over that region could be about 50 kilometers apart.
"It makes a lot of sense to do this, because then you can get the accuracy that you want without having to spend as long computing," says Budd. This approach can also be used to follow a tsunami, for example, or to understand a flame front.

Budd first learned about the concept of a moving mesh from Russell. The two met in the 1980s during a workshop that Budd organized at Oxford University where he was a research fellow at the time. They hit it off and met again shortly after at another conference in Dundee. "Bob, at that point said, 'Look, we're getting on really well. Why don't you come over and visit me at some point in the next year or so?'," says Budd who took him up on the offer. Within a year, he took a sabbatical and along with his wife and newborn daughter headed to Vancouver where they would stay a few months, spending time with family and, in Budd's case, collaborating with Russell and his colleagues at Simon Fraser University. Three decades later, their collaboration — and friendship — is still going strong. The partnership has also resulted in exchange programs between Budd and Russell's students as well as joint workshops and conferences held both in Canada and the UK.

> **"The larger the number of points in the computational mesh, the more accurate the calculation. but, at the same time, the longer the calculation takes."**

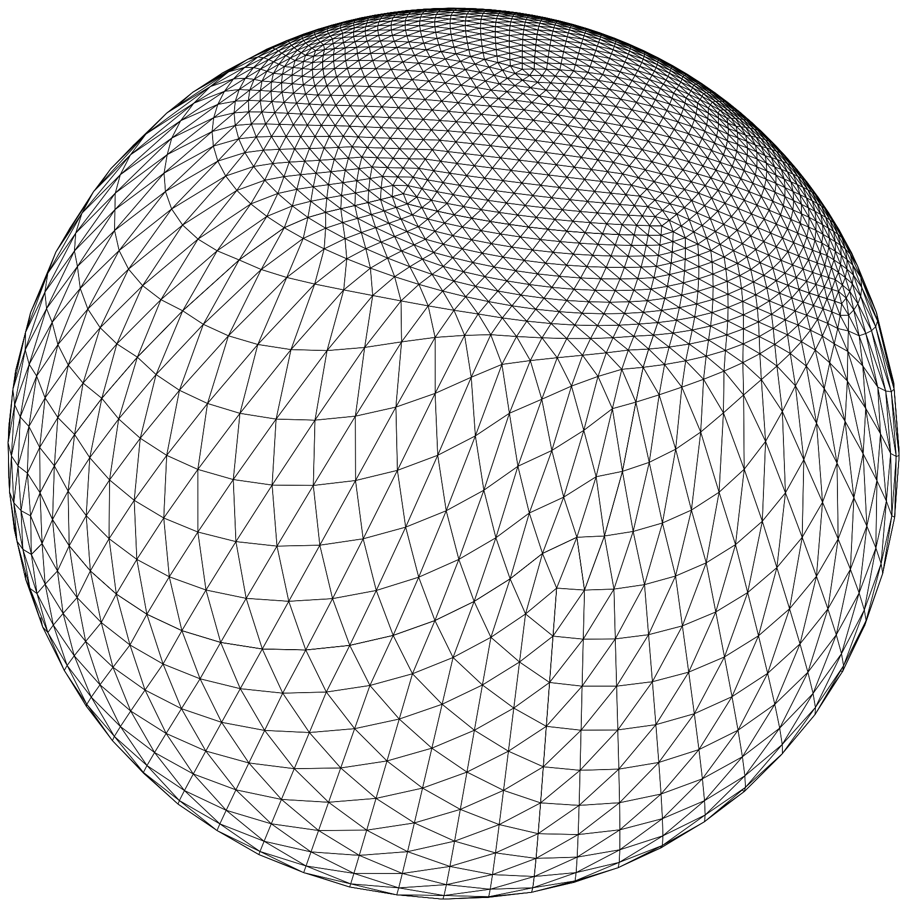
"It's just been a huge and really positive collaboration between our two nations," says Budd.

Over the years, Budd has also partnered with the UK Met Office to apply these moving mesh methods as a way to better understand inversion layers — deviations in the atmosphere where warmer air is held above cooler air. These layers are meteorologically important because they result in things like fog and pollution.
In the late 2000s Budd, along with his student Emily Walsh, collaborated with Chiara Piccolo at the Met Office to incorporate the mesh methods into operational codes the Met Office uses to forecast the weather. "It worked very well," says Budd. "As a result of this, they could show that the forecast accuracy was improved, quite a lot." Walsh then went to Canada to work with Russell before returning to be a lecturer at the University of the West of England. She continues to collaborate with Russell's colleagues in Canada.

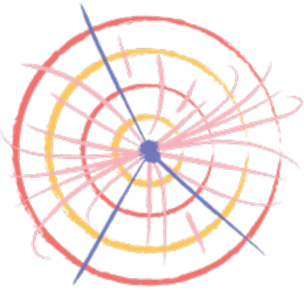
These days, Budd also gives talks to school children about climate change – a product of his collaboration not only with the Met Office but also with researchers in Canada. "In terms of impact ... for me, it's very important that I can talk about climate change to school children," he says. In addition, Budd and Russell organize workshops for researchers from around the world as a way to share their latest work and findings related to the mesh method. Their last one was in Banff in 2018 and the next one will be in Edinburgh in 2020. "We're constantly trying to develop what we're doing, come up with more challenging problems, developing new techniques."

A computational mesh, which resembles a fishing net enveloping the globe, divides up the world into smaller regions. Researchers in the UK and Canada developed a moving mesh method that adjusted the size of each mesh cell based on activity and changes in weather patterns, allowing researchers to focus on specific areas of the world. This method not only increases precision in weather forecasting but also cuts down on overall computational time.

Image courtesy of Chris Budd



This research was supported in part by UK Research and Innovation's Natural Environment Research Council and Engineering and Physical Sciences Research Council, as well as the Pacific Institute for the Mathematical Sciences in Canada.



What the Higgs Boson Discovery Means for Science and the World

And how physicists convey that meaning and impact to the general public

In July 2012, researchers announced their discovery of the Higgs Boson particle. The researchers, based at the European Organization for Nuclear Research, also known as CERN, had spent decades trying to understand the role and workings of the Higgs Boson in giving mass to the elementary particles of the universe.

The Higgs Boson was the missing piece of what's referred to as the Standard Model, which describes the fundamental particles from which visible things in the universe — including us — are made as well as how they interact. These visible particles make up four percent of the universe, and discovering the Higgs particle reassured physicists that they were on the right path in their understanding of what the universe is made of, including the origin of mass itself. The experiment — carried out by a team of physicists from around the world — took place in CERN's Large Hadron Collider. The LHC is the world's most powerful particle collider and sits about 100 metres (more than 300 feet) below the France-Switzerland border near Geneva.

"The experimental validation of this mechanism has been one of the primary endeavours of particle physics in the past decade," says Manuella Vincter, a professor of Experimental Physics at Canada's Carleton University and Deputy Spokesperson of the ATLAS Experiment, one of the two experiments that announced the discovery of the Higgs Boson in 2012. (The other was CMS, which, like ATLAS, is a general-purpose particle detector.) "This ground-breaking discovery is one of the most significant recent experimental achievements of fundamental physics."

Still, how does one convey the significance of a complex concept like this that doesn't have a direct impact on the world such as, say, the world wide web, which was also invented at CERN, or the telephone?

It's the deeper understanding that takes us forward, says John Ellis, theoretical physicist and professor at King's College London and a pioneer in the search for Higgs Boson.

"I think experience shows that every time we understand more about the way the universe works, eventually we figure out ways of using that knowledge."

This understanding, says Ellis, could be applied to medical technology, as was the case with positron emission topography – an imaging technique that uses radioactive substances to observe a body's metabolic processes, which in turn helps diagnose a disease. The technology was made possible by the discovery of antimatter. Similarly, it could be applied to hadron or radiation therapy, which uses charged particles and accelerators developed at places like CERN to treat cancer. These sorts of research efforts involve extensive international collaborations. In fact, CERN has thousands of international collaborators including a large Canadian contingent that's part of the ATLAS Experiment. Vincter and Ellis, who met two decades ago, were part of that collaborative effort. At the time, Vincter was studying the spin structure of protons and neutrons – an experiment referred to as HERMES – and, says Vincter, "John's breadth of physics interests made it such that he was the authority on a physics quantity that my experiment ... was measuring."

Both Vincter and Ellis are involved in outreach and communication of this and related research and discoveries. For instance, Vincter presents often to the community at all levels, from high school students, to their parents, to the public at large. She has also worked with science writers in Canada to formulate the significance of the discovery to the public. Similarly, Ellis has given outreach talks across the world as well as made numerous media appearances and, in the process, also influenced government policy.

Ellis acknowledges that the jargon that scientists can use to explain concepts makes it difficult to penetrate for an outsider. In fact, in a YouTube video, Ellis steers clear of jargon and instead explains Higgs Boson using the analogy of a snowfield. The influence of the Higgs Boson extends throughout all of space, like an infinite field of snow, he says in the video, which has over 500,000 views. The field is flat and featureless. "Now imagine that you are trying to cross this field of snow," he says. A skier who skims across the top is like a particle with no mass, traveling at the speed of light, that does not interact with the Higgs Boson. Somebody with snow shoes or boots would move more slowly, often sinking into the snow field, much like a particle with mass that does interact with the Higgs Boson. "Snow is made out of snowflakes; in the same way, the universal Higgs snowfield is made up of little quanta," says Ellis. "Those quanta are like snowflakes, and that's what we call the Higgs Boson."

According to Ellis, if we get past the complexity, it appears physicists are asking the same questions here as we do in other aspects of our life. He often refers to a Paul Gauguin painting, 'What Are We? Where Do We Come From? Where Are We Going?' that highlights the different phases of life from birth to death and, in the process, questions our origin and purpose from a metaphysical point of view. Similarly, Ellis says, physicists are asking what we are made of, where we came from, and what happened at the beginning of the universe.

> **"There's a lot of discussion and speculation about the future of the universe, which can be illuminated by our understanding of particle physics."**

"And then, of course, particularly these days, everybody's wondering what is going to happen in the future," says Ellis. "There's a lot of discussion and speculation about the future of the universe which can be illuminated by our understanding of particle physics."

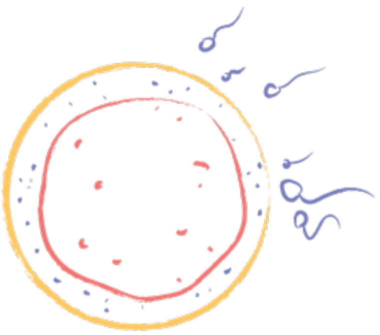
This research was supported in part by UK Research and Innovation's Science and Technology Facilities Council, the Natural Sciences and Engineering Research Council of Canada, the National Research Council of Canada, and the Canada Foundation for Innovation.

An audience waits to hear about the discovery of the Higgs Boson particle at the CERN Research Center in July 2012. This discovery helped explain how some particles acquire mass.

Image credit: CERN

> "The best way is ... to be able to think about the positive aspects of the situation."

Self-Help Tools Tackle Challenges of Infertility



Researchers develop surveys, guides, and apps to help improve an individual's quality of life

Infertility can be a deeply stressful and isolating experience. And yet 72 million people across the world experience fertility issues. Often, they have no one to turn to for help and have limited access to resources. About half follow up with a doctor.

"It's a difficult life crisis," says Janet Takefman, a professor at McGill University in Montreal, Canada, and Director of Psychological Research and Services at the University's Reproductive Health Center. "It affects family and personal well-being; it affects your job; it affects your sex life. It pretty well affects every aspect of your life, which all contribute to quality of life."

As a solution, in 2002, three organizations — the European Society of Human Reproduction and Embryology or ESHRE, the American Society of Reproductive Medicine or ASRM, and the pharmaceutical company, Merck KGaA (formerly Merck Serono International) — joined forces to create a tool that would assess the quality of life of an individual struggling with infertility. They brought in Takefman; along with her longtime colleague and friend, Jacky Boivin, professor at Cardiff University's School of Psychology; and Andrea Braverman, also a professor and Assistant Director of the Educational Core at Jefferson University in Philadelphia. The team consulted with 27 experts from across the world including researchers, psychologists, social workers, and gynecologists to identify key areas of life that are affected as a result of infertility.

Today, the tool, referred to as FertiQoL, is available in more than 45 languages as well as online on fertiqol.org. The translations are all done with local experts in mental health and in infertility and include questions such as, "Are your attention and concentration impaired by thoughts of infertility," and "Do you find it difficult to talk to your partner about your feelings related to infertility?" As a result of this approach, says Boivin, FertiQoL has helped "standardize the measurement of quality of life so that when people are doing infertility research, we're using a common patient-reported outcome."

Also in the mid-2000s, Boivin developed FertiSTAT, a tool that was designed to learn about an individual's fertility status and check themselves for signs, symptoms, and preventable causes of fertility problems. To do that, researchers developed a series of questions related to a woman's reproductive history and menstrual cycles as well as questions regarding her lifestyle such as her frequency of alcohol consumption and methods of coping with current stress. These questions were included in women's magazines and are also available online on fertistat.com.

FertiSTAT also includes questions related to the lifestyle and reproductive history of an individual's partner. Doctors use similar questions to screen individuals for factors that could influence fertility, however, the questions are adapted to accommodate cultural and religious differences. For instance, surveys taken by Sudanese populations included questions related to consanguinity, which is common in some regions of the world including parts of Africa and the Middle East.

Researchers have also created apps — FertiCalm (for women) and FertiStrong (for men) to help cope with the issue. The apps were developed by psychologists Elizabeth Grill at Cornell University and Alice Domar at Harvard University. Takefman and colleague William Petok provided content for FertiStrong.

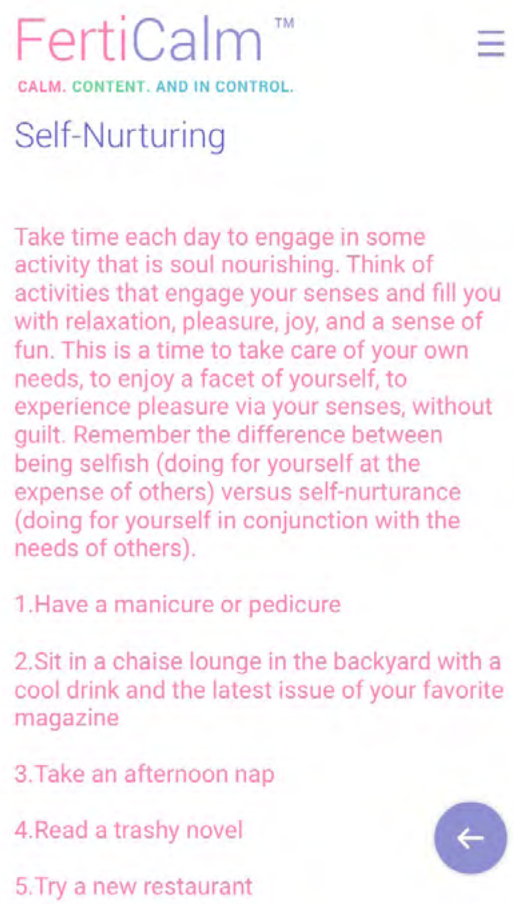
"If they're having trouble dealing with the holidays or having trouble because all their friends are getting pregnant or trouble dealing with the protocol of treatment, the apps offer coping strategies on a psychological level, on cognitive and behavioural levels, and provide relaxation exercises to help them cope," says Takefman.

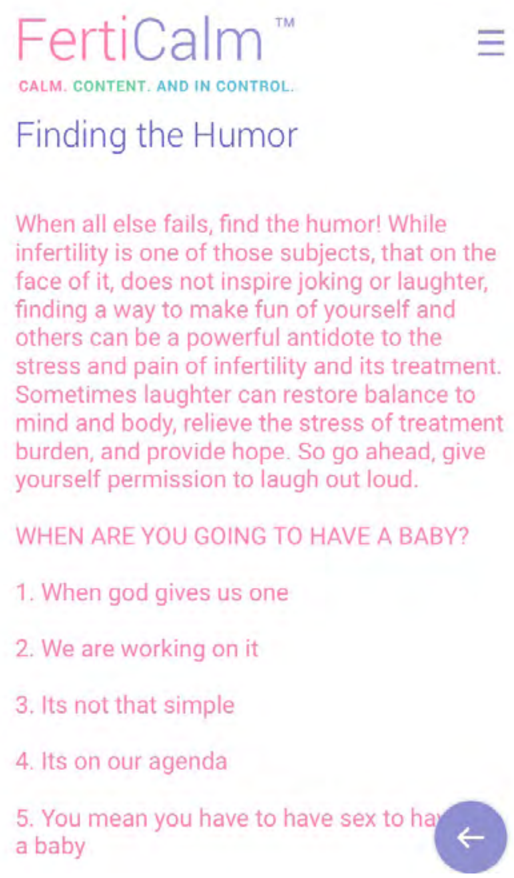
In addition to developing apps for several of these tools, Boivin developed strategies as part of a Positive Reappraisal Coping Intervention or PRCI to help cope during the seemingly endless waiting periods that often accompany medical tests and test results. "The PRCI tool is based on the theory that says that in these kinds of unpredictable, uncontrollable situations where there's nothing you can do with the outcome, the best way is to, alongside the negative of the situation, be able to think about the positive aspects of the situation," says Boivin.

The key, says Boivin, is to ensure the tools are easily accessible and essentially cost neutral to accommodate for the limited funding surrounding infertility research and treatment. She's currently working on developing infertility guidelines with the World Health Organization. In fact, Boivin says infertility is something that should be on all health agendas. She, Takefman, and others work closely with other researchers, clinics, doctors, couples, and individuals to raise awareness of the issue as well as offer strategies to manage it. To that end, Boivin also helped develop a guide to fertility that highlighted relevant topics such as when men and women are most fertile (for women it's once a month, generally close to the time of ovulation; men, on the other hand, don't have a fertile "window") and what age fertility starts to decrease (mid-30s for women; early to mid-40s for men).

Despite being in different countries, Boivin and Takefman continue their collaborations. "[Boivin] has great strengths in statistics and methodology," says Takefman. "And I think my strength is more in the clinical and design, so we try and bring it together." In fact, the duo recently worked with Emily Koert, psychologist and professor at the University of British Columbia, on an updated review of the impact of FertiQoL. Takefman also continues to bounce ideas off Boivin, always looking for another opportunity to collaborate. After all, she says, "why not work together? We get along great... she makes work fun... and two heads are better than one."

This research was supported by UK Research and Innovation's Biotechnology and Biological Sciences Research Council, Economic and Social Research Council, and Medical Research Council.





Screenshot courtesy of FertiCalm.

Apps such as FertiCalm and FertiStrong offer suggestions to deal with different situations when dealing with infertility. For example, one way to respond to questions about having a baby is with humour. The app also offers self-nurturing and other self-help tips.

A Novel Way to Clean Contaminated Soil

Researchers rely on smoldering to destroy heavy oils and solvents that spill over from industrial sites

Image credit: Dumelow/Wikimedia

An excavation shows soil contamination at an industrial site in England. In the early 2000s, researchers developed a method to smolder hazardous organic liquids such as oils, solvents, and coal tars that were found in the soil.

> **"There was a clear need for more technologies that address these particularly persistent contaminants."**

In the early 2000s, two faculty members at the University of Edinburgh, Jason Gerhard and Jose Torero were discussing soil contaminants over coffee. Gerhard, a civil engineer, was going over the list of contaminants that he was working on at the time, to which Torero, a fire safety engineer, would simply and repeatedly respond, "I can burn that."

And with that an idea was formed.

Over the course of a year, the two researchers developed a method to smolder hazardous organic liquids such as heavy oils, solvents, and coal tars that were contaminating soils on industrial sites. Experts estimate there are more than 300,000 contaminated sites across Europe and, at the time, the only way to clean sites heavily contaminated with organic liquids was to partially remove some of the liquids or simply dig up the soil and haul it to a landfill.

"There was a clear need for more technologies that address these particularly persistent contaminants," says Christine Switzer, an environmental engineer currently at the University of Strathclyde in Glasgow. In 2005, Switzer responded to an advertisement that Gerhard and Torero put out for two postdoctoral research students to develop and commercialize the process, and soon she became a core member of the team.

This technology is the first-ever to smolder heavy organic liquids in soil. It relies on the principle of smoldering combustion, using the contaminants as a source of fuel. Compare this, for instance, to using charcoal to grill food on a barbeque. You light the charcoal and first see flames. The flames then disappear and the charcoal starts to get hotter. This is a transition from flaming to smoldering, which starts off on the surface of the charcoal and works its way to the interior. The combustion is being supported by oxygen that's drawn in through the holes in the charcoal. That keeps the reaction going and allows smoldering to continue and for us to cook food with that heat.

Similarly, where soil typically has pores filled with air or water, the gaps in contaminated soil are filled with oil, solvents, and other flammable organic liquids. As part of the STAR technology, researchers add air through a well to the contaminated soil beneath the surface and ignite the contaminant locally within the soil. Once the soil is ignited, the energy from the organic liquids helps pre-heat and initiate combustion of contaminants in surrounding areas. The oxygen keeps the smoldering process going and helps destroy the contaminants in place.

After the technology was developed, the team continued to collaborate, seeking ways to scale up. "It was becoming really clear with the experiments I was doing that it worked as well at a larger scale than it did in the laboratory," says Switzer. A few years later, Gerhard moved from the University of Edinburgh to the University of Western Ontario where he is currently a professor in the Civil and Environmental Engineering Department. Torero is currently professor and head of the Department of Civil, Environmental, Geomatic and Environmental Engineering at University College London. The team still collaborates, says Switzer. "It's a relationship that has developed over the years because we all have different perspectives," she says. "It's grown quite organically, how we work together."

Today, the product is delivered commercially as "Self-sustaining Treatment for Active Remediation" or STAR by Savron Solutions, which provides solutions to treat contaminated soils and organic wastes. It has been tested across the world both in situ — in the ground itself, as well as ex situ — in a reactor. "It's now becoming more an established remediation technology rather than the new remediation technology," says Switzer.

This research was supported by UK Research and Innovation's Engineering and Physical Sciences Research Council and Scottish Enterprise.

Give Them Two Aspirin…

Researchers push for use of painkillers in lab animals to help them cope with pain

A rabbit that isn't in pain looks at the camera with its ears erect and eyes open. In contrast, a rabbit in pain appears to be wincing with its eyes closed and ears folded back. In the early 1990s, researchers argued that pain killers would greatly benefit lab animals without interfering with research results.

Screenshots courtesy of Paul Flecknell.

Lab animals — like all animals — feel pain. Why then do we not give them analgesics to help with the pain?

This was a question that Paul Flecknell first raised in the late 1970s. At the time, he was a young veterinarian with the UK's Medical Research Council and, rather than delving into the issue, had to focus his research on neonatal physiology. But about a decade later, Flecknell joined Newcastle University as a professor of laboratory animal science and began to develop a research program that explored the issue of pain in lab rodents and the use — or lack of use — of painkillers.

Each year more than 7 million research and veterinary procedures are carried out across the world on rodents and rabbits. With research in particular, scientists often hesitate to administer drugs for fear of it interfering with the study's results. But, Flecknell argued, pain could also interfere with results. In 1992, he traveled to Guelph, Ontario on a Canadian Research Fellowship and collaborated with clinical veterinarians who were developing a pain scoring system for dogs and cats. "I was there for three months, which gave me time to talk to those people and others and develop more research ideas," says Flecknell.

When Flecknell returned he began studying tattooing in rabbits — a procedure that is carried out to mark and identify the animal and involves piercing the skin of the rabbit's ear. As a way to measure pain that the rabbit might feel as a result of this procedure, Flecknell and his team measured changes in blood pressure as well as behaviour – was the rabbit wincing or vocalizing, for example. But this process was time consuming; studying changes in each animal's behaviour took at least 10-15 minutes.

Back in Canada, Jeff Mogil, a pain researcher at McGill University in Canada had developed a grimace scale based on changes in facial expressions of mice in pain, and Flecknell decided to apply that approach to rabbits by videotaping them before, during, and after the tattooing procedure. "It's a great example of how sharing your research increases its impact," says Flecknell. "Jeff Mogil published his grimace score online and provided a whole set of illustrations to help others use it."

As part of the effort, Stephanie Keating, then a veterinary anesthesia resident visiting from Guelph, watched hours of footage of the rabbits and concluded they also pull pain faces, similar to what researchers had seen in mice — squeezing their eyes, bulging their cheeks, and scrunching up their noses.

> **"It's a great example of how sharing your research increases its impact."**

"[Stephanie's] coming to Newcastle was just one of those really fortuitous things," says Flecknell. "She'd wanted to come because we were working on pain and anesthesia, and she was interested in that as a resident. It just happened to coincide with the study, so we got an extra pair of hands. It turned out that she made a major contribution to the study." The collaboration also helped Keating expand her view on pain recognition and treatment. "The experience has guided my interests and shaped my career to this day," says Keating.

In order to score pain in either rodents or rabbits, researchers take multiple photos and pick those that have the animal looking directly at the camera. They look at the eyes, whiskers, cheeks, and ears and score each expression. Researchers then add that up to get the grimace score and, based on the score, might recommend a small dose to help alleviate the pain. As part of the effort, they redo the test to determine if the painkillers they have given the animals have worked.

"We've got a rat and mouse formulary that can provide likely effective doses of analgesics," says Flecknell. "We would predict that potent or morphine-like drugs would be most effective against moderate to severe pain. The nonsteroidals — the aspirin-like drugs — will be better for mild to moderate pain." Flecknell also recommends that researchers use both types of analgesics at once, just as we would for ourselves because of the effectiveness of a multimodal analgesic approach.

One concern that often arises, however, is whether these analgesics interfere with the study results and outcome. According to Flecknell, it depends on the dosage that's administered as well as its duration. "If you just give a short treatment around the time of surgery, it's going to have minimal effects on your animal model," he says. Still, researchers must consider the differences in genetic strains of rats and mice that could affect how much pain the animals express as well as the efficacy of different analgesics.

Over the years, Flecknell has given seminars, conferences, and workshops as well as helped train veterinarians and researchers on the implementation of pain assessment methods. Several agencies and committees have adjusted their regulations regarding use of analgesics to align with the findings and recommendations. Flecknell is also helping develop an e-learning resource, which will outline facial expressions of rodents experiencing pain as well as provide information on drugs and dosage. In addition, researchers are currently exploring the possibility of using facial responses on domesticated and farm animals. "Our argument is that why create models of pain in the lab when you might be able to use some of these natural, larger animal models to study what's going on in a natural setting."

This research was supported by UK Research and Innovation's Biotechnology and Biological Sciences Research Council and Medical Research Council, the UK National Centre for the 3Rs, UFAW, Swiss 3Rs, VETO, and the Swedish Board of Agriculture

In these digitally connected times, how much privacy do individuals really have and how does the increased transparency affect society as a whole? Researchers in the UK and Canada collaborated to seek answers to these question as well as work to change data privacy and protection rules and policies.

Image credit: Michael Davis-Burchat/Flickr

Maintaining Privacy in the Digital Age

In this age of transparency, what role do governments and corporations play in protecting our data?

These days, privacy often feels like a thing of the past. Go online and you'll find heaps of information about you including where you live, work, as well as other members of your family. Granted, a lot of it can be inaccurate, but it's there for the world to see.

That information is easy enough to collect. Walk into a store, for instance, and the surveillance camera at the entrance of the store will have footage of you. Sensors in the store can detect your phone's presence. Buy an item of clothing on a credit card and that transaction is stored online. Some of that information is secure, meaning an unauthorized person can't get to it, but is it private? Can that information be sold to a marketing company studying, say, shopping patterns among a particular demographic?

"It's easy for those data sources to be analyzed in ways in which they have an impact upon people who don't even know that it's being collected and processed," says Charles Raab, political scientist and Professorial Fellow at the University of Edinburgh. In the '90s, Raab and others began arguing that data privacy extends beyond an individual's right and should be considered not just as a legal issue but as a political and social one, too. After all, how best can we ensure that all of this data that's being collected on us is used ethically by other individuals, groups, companies, and government agencies, in ways that affect society as a whole?

It was around that time that Raab met Colin Bennett through a mutual academic contact. Bennett, a political scientist at the University of Victoria, shared Raab's view on data privacy and surveillance. Together, they began working on a book — *The Governance of Privacy* — which examined the critical role and use of policy instruments and regulations in shaping and addressing data protection, privacy, and surveillance in an ever-evolving technological landscape. The first edition was published in 2003 and an updated edition was published in 2006. In 2018, the authors published a paper in which they revisited the book and discussed how those instruments have changed over the last decade and a half. Bennett is also part of the "Transparent Lives" project, which explores how surveillance in Canada has changed over the last few decades. Our lives today are much more transparent, and our activities and actions are accessible not only to the government, as it once used to be, but also to corporations and other agencies and organizations. He is also part of the "Big Surveillance Data" project, which explores how political parties capture and use voter behaviour to influence political outcomes.

When it comes to data protection, however, some countries have more sophisticated regulations and directives in place than others. The EU, for example, has implemented the General Data Protection Regulation, which lays down rules about how an individual's data can or cannot be used, including whether or not an individual has given consent for certain information to be collected or used. In addition, companies handling sensitive information must have strict protocols and safeguards in place to ensure that information stays secure and anonymous. These sorts of strictures are especially critical when it comes to handling data related to an individual's state-issued ID, for example, or health insurance. Similarly, in Canada, Bennett has worked with the network of federal and provincial privacy commissioners to ensure that Canadian rules are consistent with international privacy standards.

> **"We did have some impact on raising the level of understanding not only among academics and regulators but also among companies and law firms."**

Raab works with law enforcement agencies in the UK to ensure that their use of advanced analytic technologies and extensive sources of personal data in policing is ethical. Without proper oversight, such processes can easily have harmful consequences. Facial recognition tools are sometimes used to target ethnic and cultural groups or other minority populations. "Some American cities are banning the use of some of these technologies because they're discriminatory," says Raab. "Although they might be useful, they may also have harmful consequences for individuals and groups if they are inaccurate or used unethically."

Raab also helps advise police forces on ethical and acceptable policies regarding predictive policing — a practice that uses artificial intelligence and statistical analysis to flag individuals more likely to commit a crime. Based on those determinations, police can intervene as a way to prevent future crimes and to link with other agencies that offer help, but these practices require ethical scrutiny and oversight.

All of this work has had an impact both in the UK and Canada. In addition, *The Governance of Privacy* is cited in other papers and reports and has helped some regulatory officials gain insights into how to develop their work and organizations. It has helped regulators and advocates understand that privacy protection is not just about the "black letter of the law" but about a broader array of policy tools.

"I think we did have some impact on raising the level of understanding not only among academics and regulators but also among companies and law firms about how one might go about thinking about the regulation of privacy," says Raab.

This research was supported by UK Research and Innovation's Economic and Social Research Council and the Social Sciences and Humanities Research Council of Canada.

How Researchers Combined Genetic Engineering Techniques and Mathematical Analysis to Get More Seed Oil

One enzyme played a key role in the oil production process of the canola plant

Visit a canola field and you'll see endless miles of bright yellow flowers. Oil made from canola seed or rapeseed, as it's still known in Europe, is often used in cooking and baking, and it's within the seeds of these radiant plants that the oil forms.

In 2004, Randall Weselake, who is currently a Professor Emeritus at the University of Alberta's Department of Agricultural, Food and Nutritional Science, and John Harwood, a professor at Cardiff University's School of Biosciences joined forces to find a way to make the oil formation process more efficient. Oils such as those from canola and olive are high in unsaturated fats, which are known to have many health benefits — they help with weight loss as well as control cholesterol levels, for example — and demand for plant oils is going up at around five percent per year.

Canola oil, much like olive oil, is high in monounsaturated fat in particular, which means it contains only one double bond (or point of unsaturation) in the fatty acid chain. In contrast, polyunsaturated fats that are found in sunflower and sesame oils contain multiple double bonds in the fatty acid chains. Seed oils are enriched in viscous triacylglycerols or TAGs — compounds made up of three fatty acids attached to a glycerol backbone. Through decades of research, scientists discovered that the enzyme, diacylglycerol acyltransferase, or DGAT, is responsible for catalyzing the formation of the TAG through addition of the final fatty acid chain on the glycerol backbone. However, in the 1990s, Harwood's team found that a bottleneck occurred at that final step leading to TAG accumulation in canola seed. The finding suggested that removal of this bottleneck would help increase overall oil production in the plant.

At the time, Harwood's team had also performed flux control analysis on TAG formation pathways in various oil-forming

Bright yellow fields of Canola in East Central Saskatchewan stretch across miles. Researchers in the UK and Canada collaborated to develop a method involving genetic engineering and mathematical analysis that would help increase production of canola oil.

Image credit: Nas2/Wikimedia

"Since we've published our work, there have been a plethora of studies published on over-producing DGAT in various organisms."

plant systems. Flux refers to the movement of carbon through a metabolic pathway and how each enzyme-driven reaction in the pathway contributes to the overall flux. The information used in the mathematical analysis of flux is based on feeding studies with radiolabeled fatty acids and inhibitors of specific enzymes in the pathway using oil-forming plant tissues or cultures. "By these means one can identify which part of the pathway should be modified to increase flux," says Harwood.

Before the two met, Weselake and his colleagues at Agriculture and Agri-Food Canada in Lethbridge and Saskatoon, Alberta Innovates Technology Futures (formerly known as the Alberta Research Council), the National Research Council of Canada in Saskatoon, and the University of Calgary were investigating a genetic engineering approach to increase the abundance of DGAT in developing canola seeds as a possible means of increasing seed oil content. When they met at an International Symposium on Plant Lipids , they realized the value of working together. "Once we started using flux control in Cardiff, it seemed an obvious collaboration to work together on rapeseed oil," says Harwood. "That was when our joint research (and friendship) began."

To test the theory that opening up the TAG formation bottleneck would result in more oil formation, Harwood implemented a top down control analysis of two major metabolic blocks contributing to seed TAG formation. Block A refers to processes contributing to fatty acid formation whereas Block B refers to processes contributing to TAG assembly. In the normal or wild-type canola, the analysis showed 70 percent control was associated with Block B: the TAG assembly block. Meanwhile, in the genetically engineered seeds, metabolic control dropped to 50 percent. "There was overall less control in the oil formation block in the genetically engineered lines," says Weselake. "Thus, by making more DGAT available during seed development, we could in fact overcome the bottleneck in the oil formation process." The findings further indicated that metabolic control analysis may be useful in developing future genetic engineering strategies to produce value-added compounds in seeds.

The researchers tested these methods both in the lab and in the field and found that oil production increased in both circumstances. The paper was published in 2008 in the *Journal of Experimental Biology* and went on to be highly cited. "Since we've published our work, there have been a plethora of studies published on over-producing DGAT in various organisms," says Weselake. Although this genetic engineering approach hasn't been implemented in Canada, according to Weselake, if applied, the country's oilseed crushing and processing industry could potentially make an additional $100 million per year if seed oil was increased by only one percent on an absolute basis. "Just small increases could result in enormous economic benefit."

This research was supported by UK Research and Innovation's Biotechnology and Biological Sciences Research Council, the Alberta Agricultural Research Institute in Canada, the Alberta Crop Industry Development Fund, Canada Research Chairs Program, Canada Foundation for Innovation, Natural Sciences and Engineering Research Council of Canada, and the University of Alberta.

How One Researcher Used Physics to Expose a Fraudster

Fake bomb detectors sold for thousands of dollars each contained nothing but a few wires connected to a cheap antenna

The ADE 651 was believed to be a bomb detector, however, physicist Michael Sutherland opened it up to find nothing but a few wires. This bogus device was sold for a lot of money and put several lives at risk.

Image credit:
Your Funny Uncle/Wikimedia

In September of 2010, Michael Sutherland got a call from London's Metropolitan Police Department, asking if he could test the authenticity of a bomb detection tool.

The tool, the ADE 651, was a handheld device that was fitted with a swivelling antenna. The purpose of the antenna was to detect the presence of a bomb based on its interaction with tiny electromagnetic signals. The company that produced ADE 651 — Advanced Tactical Security & Communications Ltd. — had sold millions of dollars' worth of these devices to numerous countries including Iraq, Pakistan, and Lebanon. Although the British military had already done a cursory test of the tool in the field, it wanted a more rigorous, scientific assessment.

Enter Sutherland, a condensed matter physicist at Cambridge University, who studies the response of metals, magnets, and other similar materials to weak electromagnetic signals.

"Looking at these devices and thinking about what I've learned from my research in detecting small signals, it was pretty obvious there's no real physics behind these devices," says Sutherland. In fact, when he opened them up, he found an empty plastic handle with a few small wires connected to the antenna. "These things could have been built for a few pounds from components sold at eBay, but they were being marketed for thousands of pounds," he says. In addition, there was no power source and although the company claimed the devices could be charged by static electricity, the physics of it all simply didn't check out.

> **"These things could have been built for a few pounds from components sold at eBay."**

Still, Sutherland decided to further test these devices in the field. With assistance from the military, he went to a disused airplane hangar on a military base armed with a little over two pounds of TNT — an explosive yellow solid — and six empty boxes. As part of the experiment, Sutherland would leave the area while an assistant placed the TNT under one of the boxes. He would then return and use the detector to determine which box had the TNT. "You do this 20 or 30 times," Sutherland says. "And of course, it showed that it was no better than random chance at selecting the right box."

A few months later, Sutherland was called in as an expert witness to testify at the hearing of James McCormick, head of ATSC. Shortly after, McCormick was sentenced to 10 years in prison as well as ordered to pay back 8 million pounds. (In 2018, his jail term was extended by more than two years because of his failure to pay back 1.8 million pounds, as reported in The *Guardian*.) "The worst thing in my opinion was that people likely lost their lives due to the false belief that these devices could detect car bombs or mines," says Sutherland. "It's an absolute travesty all around."

Originally from Canada, Sutherland did his PhD in condensed matter physics at the University of Toronto. In 2004, he came to the UK on a postdoctoral fellowship provided by the Natural Sciences and Engineering Research Council of Canada. He continues to collaborate with colleagues in Canada, focusing his research on superconductors and on topological insulators — materials that are electrical insulators on the inside but have a thin conducting layer on the surface arising from exotic quantum mechanical interactions. These materials are studied for their application in electronics — potentially for use as transistors in quantum computers and in ultra-efficient devices with low power consumption. "People around the world are researching these materials both for their exciting technological applications, but also for the interesting fundamental physics questions they raise which require input from the field of mathematics known as topology," says Sutherland. "I think this is definitely a hot area for physics research worldwide."

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The Air We Breathe

Researchers develop a computer simulation model to measure pollution levels in our homes, offices, and other microenvironments

Apartment buildings along the Arabian Sea in Mumbai, India, are clouded in smog. In the early 2000s, two researchers developed a computer simulation model to measure the levels of pollution that individuals are exposed to in their homes, offices, schools, and other microenvironments on a daily basis.

Image credit: Divya Abhat

> **As Newton famously said, solving one problem leads to 10 others.**

Air pollution levels are regularly monitored in urban areas across the world. These levels are typically measured by outdoor monitors that are placed in different parts of a city. But how about microenvironments? What levels of pollution are generated by fireplaces, cookers, and vacuum cleaners? What levels are experienced in an office building, a restaurant, or a car cabin, for example?

In 2002, on a visit to Bath, James Zidek, then a visiting professor in the Department of Mathematical Sciences at the University of British Columbia, met Gavin Shaddick, at that time a lecturer in the Department of Mathematical Sciences at the University of Bath. "Gavin and I discovered that we had complementary research interests, and I drafted a research plan that was expected to take six months to complete," says Zidek, who is now a Professor Emeritus at the University of British Columbia. The plan involved the assessment and application of a computer simulation model called pCNEM that simulated human exposures to air pollution, as random individuals moved at random through microenvironments such as their house, a school, or a restaurant throughout the day.

"What we really want to do is estimate individual exposures to air pollution," says Shaddick, who is currently Chair of Data Sciences and Statistics at the University of Exeter. To do that, the researchers used the simulator to generate virtual individuals and follow them throughout the day, which is segmented into chunks of random duration, as they move from one microenvironment to the next. Researchers were then able to estimate the computer simulated individuals' exposure to air pollution based on their activities and locations. Next, they grouped the individuals based on age, population, and location. "We need to know where people spend their day, what the levels of air pollution are in each microenvironment, and how long people spend in them," says Shaddick. "And that is the basis of what's known as a personal exposure simulator model."

Although pCNEM isn't the first or only model that does that, it's unique in its ability to account for uncertainties. "We don't know where people actually spend their time, and we don't really know the level of air pollution in everybody's kitchen," says Shaddick. "So, we allow for some uncertainty in the input to the model, and then we can predict what an individual person is exposed to." In addition, a computer simulation model allows for researchers to simulate thousands of individuals and, in the process, simultaneously study numerous microenvironments and personal exposures to air pollution. In contrast, while a personal exposure monitor that's worn by an individual would potentially be more precise and accurate, it simply lacks that kind of scope. pCNEM also creates hypothetical scenarios based on changes in air pollution policies, which helps researchers and policy makers assess the potential impact of a particular regulation.

Today, Zidek and Shaddick, along with their colleague Michael Brauer, a professor at the University of British Columbia, produce accurate estimates of exposure to air pollution around the world as part of the World Health Organization's Data Integration Task Force for Air Quality, which is led by Shaddick. In addition, the models for estimating personal exposures have been used in scientific research to determine air quality standards for ozone and have also had an impact on public policy and legislation. In addition, the researchers co-supervised students, who, according to Zidek, "have benefited from the combination of two different research fields as well as differences in the different academic climates in the UK and Canada."

Both Zidek and Shaddick expect collaborations to continue. "As Newton famously said, solving one problem leads to 10 others," says Zidek. "Because of that he and I have a good many papers and a textbook, most all in spatial or environmental statistics, in particular the health effects of air pollution."

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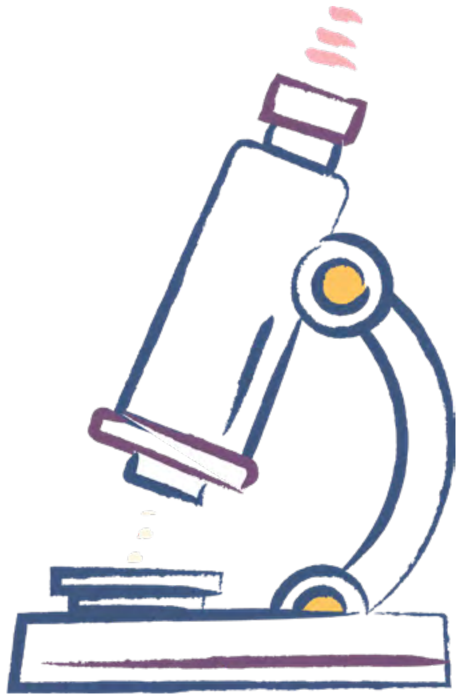

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