



OPEN ACCESS GOVERNMENT

NORTH AMERICA ANALYSIS

70

SUPPORTING THE URBAN ABORIGINAL POPULATION IN CANADA

INDIGENOUS AND NORTHERN AFFAIRS CANADA EXPLAIN
HOW THE ORGANISATION IS WORKING TO BETTER THE LIVES
OF THE URBAN ABORIGINAL POPULATION IN CANADA

IN THIS ISSUE

Dr Christopher Lynch, Director of the Office of Nutrition Research explores the links between diet and health in an interview with Editor Laura Evans

Virginia Guidry and Kimberly Gray from the NIEHS outline how environmental health science can help to identify potential hazards in a child's environment

As antibiotics become less effective against infection, Minister of Health, **Jane Philpott**, outlines the response to antimicrobial resistance in Canada

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INTRODUCTION

Welcome to the August edition of Adjacent Open Access – North America Analysis. In this supplement we look at a number of key areas within Canada and the US such as, healthcare, the environment and science.

The edition starts with a piece from Dr Chris Lynch, Director of the Office of Nutrition Research at the US National Institutes of Health (NIH). In an interview with Editor Laura Evans, Dr Lynch explores the links between diet and health. We also highlight Huntington's disease with an article from Jennifer Simpson from the Huntington's Disease Society of America. In her piece, Jennifer outlines why there is still a long way to go before the disease can be truly understood.

Also in the US section of the supplement, focus is given to environmental health science. Virginia Guidry and Kimberly Gray from the National Institute of Environment Health Sciences, NIH, discuss in their article how it can be used to identify potential hazards in a child's environment. We also shed light on the work of the National Science Foundation (NSF), and how they support work to tackle climate change and help to protect marine health.

The Canadian section kicks off with an excellent piece from Minister for Health Jane Philpott. Her article focuses on the work of the Canadian government to tackle antibiotic resistance. A global problem, AMR reduces the effectiveness of antibiotics, making it hard to treat certain infectious diseases. Philpott

outlines the Canadian Action Plan and how they are strengthening systems to tackle and prevent the problem.

Minister for Transport, Marc Garneau also writes an article in this section, which outlines the importance of the transportation network for Canadian communities, as well as the economy. We also outline the work of the Natural Sciences and Engineering Research Council (NSERC) to pioneer scientific advancement in Canada.

Other topics we take a closer look at in this edition include, support for Indigenous communities, research excellence in Ontario, speech and language problems, as well as forests and biodiversity.

As always, I hope you find this edition informative and I welcome any comments that you may have. ■

Laura Evans
Editor



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Nutrition research is vital for healthy outcomes

Dr Christopher Lynch, Director of the Office of Nutrition Research explores the links between diet and health in an interview with Editor Laura Evans

The U.S. Center for Disease Control (CDC) reports that in America more than 2 in 3 adults are considered to be overweight or obese, with more than 1 in 20 adults seen as having extreme obesity. They also say that one-third of children and adolescents aged 6 to 19 are considered to be overweight or obese.

Poor nutrition is a problem that can have devastating effects on someone's health, contributing to heart disease, some forms of cancer, stroke and Type 2 diabetes. Four out of 10 causes of death in America are said to be diet related, according to the American Society for Nutrition.

Understanding the importance of nutrition is key to ensuring good health. Having relevant information and knowing the risks that come with making unhealthy food and beverage choices could help prevent many diseases from developing.

Research plays a key role in understanding the health problems related to nutrition. The Office of Nutrition Research (ONR) at the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), NIH is responsible for leading nutrition research efforts across NIH Institutes and Centres. To gain insight into this topic, Editor Laura Evans speaks to Dr. Christopher Lynch, director of the ONR, about the value of nutrition research and the many challenges in this field.

"In the US, chronic diseases account for 75% of the National Health Expenditure and diet and nutrition is a major factor in those diseases," and according to Dr. Lynch, about 170 million Americans have one or more diet-related chronic disease (diabetes, obesity, diet related cardiovascular diseases, stroke and certain cancers). "The public is very interested in nutritional research because many recognize that there is a link between diet and disease.

Nutrition research funded by NIH assists other federal agencies, such as the Food and Drug Administration, to create policies and make regulatory decisions. “Nutrition research is also important for national security”, he says. In the US, we have the National School Lunch Program. It was implemented around the time of the Second World War to safeguard the health and well-being of the nation’s children. A factor in establishing the programme was the number of malnourished young draftees that were turning up to serve in the military. Presently, we have the converse problem. Although we no longer have a draft for the military, we still have health requirements to join. Now, many young people who are applying are too overweight to join. In fact, one quarter of America’s youth are too overweight to serve in the military.”

Strategic plan for nutrition

In order to develop their first NIH-wide strategic plan, the NIH formed the Nutrition Research Task Force (NRTF) to coordinate and accelerate progress in nutrition research. That group will guide the development of the nutrition research plan for the next 10 years. They hope to complement and enhance ongoing research efforts on diseases and conditions affected by nutrition, such as diabetes and cardiovascular diseases.

“While each of our institutes and centres at NIH may focus on particular organs, diseases or aspects of health, nutrition is a scientific discipline that crosses institutional boundaries. That’s why coordination and strategic planning is important,” adds Lynch. “Research will be coordinated between NIH Institutes and Centres through the strategic plan to ensure the teams are working toward common agreed upon goals.”

Challenges and Opportunities

The Nutrition Research Task Force is considering many challenges and opportunities in nutrition research. One opportunity is to improve the reproducibility and scientific rigor of nutrition research. At times, research findings and media reports can be at odds with one another. Research from different studies can be at odds with one another too.

“Understandably, people get upset if they find out that a food that they enjoy could promote disease, after previously being told it was safe. This then creates a

ground for people to condemn the scientific process more broadly,” says Lynch.

“Getting the correct information about nutrition and the elements of a healthy eating plan out to the public is essential.” This, Lynch explains, is one of the many challenges that the public faces when trying to adopt a healthy diet. “Therefore, developing approaches to improve communication, reproducibility, and rigor of scientific data will be a focus of our efforts”

Presently, many nutrition studies only rely on the participants’ recall of what they consumed. “This is something that our task force has to address,” explains Dr Lynch. “We need to develop new approaches for assessing nutritional intake and status that don’t rely entirely on people self-reporting. New tools and technologies are emerging that could help address this, so now is a good time to start taking full advantage and apply these tools to nutrition research.”

“Another key scientific gap we hope to address pertains to the nutritional requirements for pregnant moms and children from birth to 2 years of age for healthy development. Early life exposures to dietary components or feeding practices may have long term consequences for susceptibility to chronic diseases later in peoples’ lives, and even inter-generationally, through a process known as nutritional programming or epigenetics. We need to understand the permanency, and reversibility of these phenomena.”

Recent studies suggest that some dietary patterns are healthier than others. A challenge will be to understand the physiological mechanisms through which these diets effect health. Another concept is that people’s responses to diet interventions may be “personal”. As is the case for precision and personalised medicine, people’s responses to dietary patterns or even specific foods within those patterns appears to vary between individuals. So, a key challenge is to understand the mechanisms through which healthier dietary patterns, such as the Mediterranean Diet, work, and the basis of interpersonal variability in physiological/metabolic responses to certain foods.

“Our task force is also exploring how to best harness data from many sources that are collected today

Typical values	100ml contains	250ml contains	%GDA*	typical adult
Energy	199kJ 47kcal	500kJ 120kcal	6%	2000kcal
Protein	0.5g	1.3g		
Carbohydrate of which sugars	10.5g	26.3g	29%	90g
Fat of which saturates	10.5g	26.3g		70g
Fibre	trace	trace		
Sodium	trace	trace		
Salt equivalent	trace	trace		

*Guideline daily amounts

Vitamins/Minerals

100ml contains
25.0mg (42% RDA) 62.5mg

(grocery store inventories, federal databases keeping epidemiological and molecular data, global positioning systems (GPS) data, personal health information, social media, credit card purchases etc.), so called 'big-data', to help us address questions about nutrition, diet behaviours, and food insecurities of the population."

Finally, Lynch explains, "it has long been known that microbes co-habitat our bodies. Some of these are felt to be beneficial whereas others are potentially detrimental. There is emerging evidence that those that make our gut their home may be releasing substances or otherwise communicating with us, their hosts, and having an impact on disease or eating behaviour.

"It is likely, therefore, that a focus of the strategic plan will also be the relationship between diet and the gut microbiome along with the microbiome's relationships

to behaviour and disease, and the underlying mechanisms involved. Obviously, our strategic plan also must address how to train the next generation of nutrition research scientists in some of the emerging methodologies, informatics and technologies to address our strategic goals." ■

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www.twitter.com/NIDDKgov

Can blueberries help to tackle many global health problems?

Mark Villata, Executive Director, U.S. Highbush Blueberry Council highlights many health benefits associated with blueberries

The US Highbush Blueberry Council (USHBC) is one of 22 national agricultural Federal Research and Promotion Boards. It was established in 2000 under the Blueberry Promotion, Research, and Information Order and consists of members who are blueberry farmers, processors, importers, and public representatives. The members are nominated by their peers and appointed by the Secretary of Agriculture. The USHBC does not sell any product, and operates with oversight from the USDA.

“Fruits and vegetables have been shown to have many health benefits however approximately 75% of Americans are not meeting the recommended daily intake for fruit.”

The USHBC's operations are funded by assessments collected on highbush blueberries produced in and imported into the United States. The assessments are paid by producers and importers of 2,000 or more pounds of blueberries annually. Highbush blueberries are now available to US consumers all year round. The global blueberry market has grown 40% since 2012, and is projected to surpass 1.4 billion pounds this year. The USHBC is organized into committees that focus on various aspects of the blueberry industry including communications and promotions, good management practices, industry relations and health research.



Health benefits of blueberries

The Health Research Committee solicits its research proposals designed to evaluate the health effects of blueberries. Over the past 15 years, the Council has supported studies from over 30 different academic institutions. The objective of the USHBC is to fund well-designed studies from qualified researchers, who can then use the data as support for larger studies in the future, if the results are promising. With limited federal funding for nutrition research at both NIH and the USDA, funds provided by commodity groups such as USHBC help to support nutrition researchers, particularly those that are at the early stages of their careers.

The research studies that USHBC fund evaluate the effect of consuming the whole blueberry rather than an extract or an isolated component. Blueberries are a good source of fiber, are low in fat and high in vitamin C. In addition, they are a source of bioactive plant compounds such as polyphenols, flavonoids and anthocyanins. In 1998, a paper was published showing that when various fruits and vegetable were tested for their in vitro antioxidant activity, blueberries were among the highest in antioxidant activity.¹

Current health research in blueberries has advanced beyond the initial interest in the antioxidant activity. Over the past 15 years, the USHBC has sup-

ported studies in the areas of cognitive function, insulin response, cancer, and cardiovascular health. We have also begun new research studies to see how blueberries in the diet can affect the gut microbiome.

When the Council was first formed in 2000, some of the first studies funded were those led by Dr. James Joseph at the USDA Human Nutrition Research Center for Aging at Tufts University. Dr. Joseph was one of the first scientist to look at the effect of blueberries on brain function with aging. Through his animal studies, he was able to show that by supplementing the diet with blueberries, a group of older rats performed as well as young rats in tests of memory and balance.² The Council continues to fund studies by other scientists in this area. Recently a human study by Dr. Shukitt-Hale demonstrated that older subjects who consumed blueberries, in the form of freeze-dried powder, had fewer errors on a test used to assess verbal memory abilities, and made fewer errors when forced to switch from one mental task to another when compared to a group who were given a placebo powder instead of blueberry powder.³

Given that a third of the US population is considered obese⁴, the Council has investigated whether consuming blueberries would improve some of the complications associated with obesity, such as insulin resistance.

Several studies have been funded to determine if adding blueberries to the diet could affect insulin resistance. When animals were fed a high fat diet

in order to induce obesity and insulin resistance, the group that were also fed blueberries showed a decrease in insulin resistance when compared to the group that did not receive blueberries.^{5,6} This effect was also seen in humans who were given blueberries and were evaluated using a glucose clamp procedure.⁷

Reducing the incidence of disease

Vascular disease is a major killer of adults in the US. High intakes of fruits and vegetables have been associated with a decreased incidence of cardiovascular disease, and the effect of consuming blueberries in this area has been studied. In two separate studies, researchers saw a slight but significant decrease in blood pressure in subjects who were obese or had mildly elevated blood pressures after they consumed blueberries for 8 weeks.^{8,9}

“The global blueberry market has grown 40% since 2012, and is projected to surpass 1.4 billion pounds this year.”

Triple negative breast cancer is a type of cancer that is difficult to treat as the tumors are often not responsive to available drug treatments. Although no studies have been conducted with human subjects, animal studies have shown a reduction in tumor size and growth when blueberries were added to the diets of mice.^{10,11}

Fruits and vegetables have been shown to have many health benefits however approximately 75% of Americans are not meeting the recommended daily intake for fruit.¹² The USHBC will continue to support research studies to

determine if specific health benefits can be attributed to the consumption of highbush blueberries and with careful, evidence-based communications to the public, hopefully more consumers will choose to increase their intake of fruit, including blueberries. For more information on the USHBC, go to www.blueberry.org.

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Huntington's disease: Understanding the impact

Jennifer Simpson of the Huntington's Disease Society of America highlights the disease and how there is still a long way to go before it can be truly understood

Since the discovery of the gene that causes Huntington's disease in 1993, exponential progress has been made in elucidating the true scope of Huntington's disease, but there are still miles to go to truly understand the impact of symptoms of HD families. Huntington's disease (HD), is an autosomal dominant neurological disease caused by an expanded CAG repeat in the Huntingtin gene. The disease is characterised by progressive functional decline and motor, psychiatric and cognitive symptoms, in addition to weight loss, sleep disturbances and dysregulation of the autonomic nervous system¹. Each child of a person who carries the gene mutation that causes HD has a 50% chance of inheriting the faulty gene.

“Although we currently have no cure for this disease, we do have the ability to allow individuals to access treatments to help them manage this debilitating illness. While we work on a cure and find hope for tomorrow, we have to ensure that families affected by HD can access the help they need today.”

Cognitive and behavioral symptoms are most impactful to HD patients and families

In preparation for a Patient Focused Drug Development meeting with the U.S. Food and Drug Administration, the Huntington's Disease Society of America (HDSA) surveyed the HD community in the U.S. on topics related to HD symptoms and treatments. Between two surveys, more than 3,600 responses were collected from individuals affected by HD, Juvenile Huntington's disease (JHD) and caregivers for those with HD and JHD. In reviewing the data collected, clear trends began to emerge between caregivers and HD/JHD patients alike. Caregivers responded most frequently that chorea was the most impactful symptom of HD (30%), but in aggregate, behavioral and cognitive symptoms were

reported as the most impactful to their lives by more than 50% of both caregivers and HD/JHD patients².

Huntington's disease has long been classified as a movement disorder, though prodromal features encompass cognitive and behavioral symptoms of HD³. Although classified as “prodromal”, the cognitive and behavioral symptoms of HD are major elements of the disease and its impact on the individual and their families. Cognitive and behavioral symptoms can manifest as much as a decade before motor symptoms develop, and as a result often go undiagnosed as symptoms of HD. It is not uncommon for individuals with HD to be misdiagnosed with a variety of psychiatric disorders before being correctly diagnosed with HD at the onset of motor symptoms. Delayed diagnosis may unfairly disadvantage people with HD and cognitive-behavioral symptoms, especially in terms of accessing the kind of care and benefits people with HD really need to best manage the progression of their disease⁴.

For Huntington's disease patients, treatment options are lacking

In the world of HD, treatment options are few and far between. As of the publication of this article, only two medications exist that are FDA approved for the treatment of HD, and both treat chorea symptoms associated with the disease. Currently, there are no disease-modifying treatments or cures. When surveyed on availability and efficacy of current treatments for cognitive symptoms of HD, more than 80% of respondents noted that they or their loved one were not taking any kind of medication for symptoms like deterioration of memory and thinking². For behavioral symptoms like anxiety, depression and irritability, individuals responded most frequently that they or their loved one was not taking any kind of medication



to treat those symptoms². The lack of treatment options, especially for cognitive symptoms of HD, stands in stark contrast to the impact those symptoms have on the lives of people with Huntington's disease.

Access to care early on is critical to managing Huntington's disease

As patients with HD become symptomatic, it is key that those individuals have access to comprehensive care with doctors who are knowledgeable in HD. HD patients in early to middle stages of the disease need coordinated multidisciplinary healthcare services, including assessment of cognitive function and counselling by (neuro) psychologists, rehabilitation programmes, active physiotherapeutic interventions, speech therapist training and occupational therapy⁵. Lack of access to care for families with HD means unmanaged or poorly managed symptoms, higher rates of caregiver burnout, potential unnecessary hospitalisations and early entry into long-term care facilities. With access to specialists knowledgeable in HD, families can avoid unnecessary additional emotional and financial burdens. In the U.S., HDSA has created a

clinical care model through the Center of Excellence programme, awarding grants to HD clinics around the country to provide an all-in-one service center for families affected by Huntington's disease. HDSA currently funds 41 Centers of Excellence around the U.S.

“In the world of HD, treatment options are few and far between. As of the publication of this article, only two medications exist that are FDA approved for the treatment of HD, and both treat chorea symptoms associated with the disease. Currently, there are no disease-modifying treatments or cures.”

Expanded access to government programmes can help HD families

Individuals with HD access multiple forms of governmental support as their disease progresses. Because HD symptom onset commonly occurs during prime working years, many families are devastated financially, and need to rely on programmes like Social Security Disability Income (SSDI), Medicaid and Medicare. Utilising these programmes can help families access professionals like neurologists, neuropsychiatrists,

speech therapists and physical therapists. Expansion of Medicaid programmes has resulted in a reduction of unmet need for mental health services, in addition to positive impacts on the budgets of states that expanded Medicaid as states no longer needed to use some of their general funds to pay for behavioral health treatment for the uninsured⁶. Individuals with HD are included amongst those who have benefitted from the expansion of programmes like Medicaid, and would further benefit from expedited access to Medicare through the Social Security Disability Income programme. HDSA has been advocating, alongside the HD community, for a waiver of the two-year Medicare waiting period for individuals who are disabled by Huntington's disease and utilising the SSDI programme. The Huntington's disease Parity act of 2017 is a bi-partisan solution to an HD shaped hole in the social safety net. It is one step of many to help ensure access to important behavioral health services and specialist neurologists who can assist families maintain quality of life for folks with HD for as long as possible. Although we currently have no cure for this disease, we do have the ability to allow individuals to access treatments to help them manage this debilitating illness. While we work on a cure and find hope for tomorrow, we have to ensure that families affected by HD can access the help they need today. ■

“The disease is characterised by progressive functional decline and motor, psychiatric and cognitive symptoms, in addition to weight loss, sleep disturbances and dysregulation of the autonomic nervous system¹. Each child of a person who carries the gene mutation that causes HD has a 50% chance of inheriting the faulty gene.”

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Huntington's disease: Investigating pathogenic mechanisms

New York University School of Medicine's Naoko Tanese explores the pathogenic mechanisms and therapeutic strategies for Huntington's disease

Mutation in the huntingtin (HTT) gene causes Huntington's disease (HD), a dominant, heritable, neurodegenerative disease. The normal human HTT gene encodes a large protein whose function remains elusive. Extensive studies of the normal and mutant HTT protein have identified roles in the maintenance of proper cell structure and function, transport of key molecules within cells, regulation of gene expression, among others. HD is characterised by the appearance of aggregates visible in cells under a microscope, and degeneration of specific regions of the brain. Although the HTT protein is expressed throughout life, most patients develop symptoms in mid-life. Current evidence suggests that mutant HTT protein causes significant dysfunction of neurons as the disease progresses, ultimately resulting in cell death.

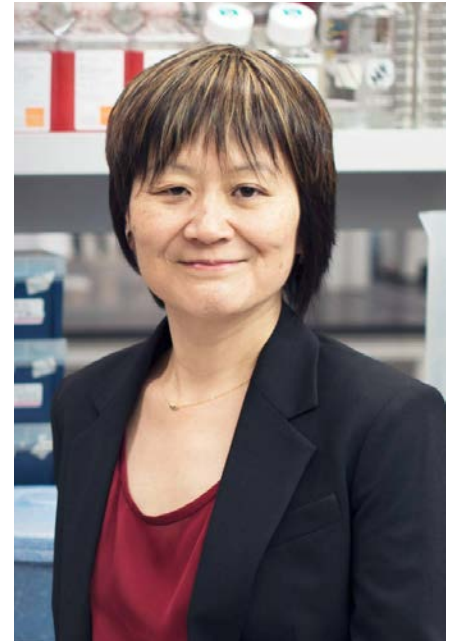
Altered RNA metabolism is linked to neurological disorders

Mutations in a variety of genes cause neurological disorders. Of particular interest are genes that encode proteins that bind RNA. RNA molecules are so-called messengers of DNA, the blueprint of genetic information stored in each cell. RNA molecules are copies of DNA with instructions to make proteins specified by the DNA, a process termed gene expression. There are many proteins whose function is to bind RNA and regulate different steps in gene expression. These proteins

bind RNA and control its stability and location within the cell. RNA binding proteins also regulate efficiency with which proteins are made by the ribosome, the machine that synthesises proteins. In response to stressful conditions, RNA binding proteins and RNA can form granules inside the cells. Under normal conditions, these types of granules also serve to transport RNA to distal sites where protein synthesis takes place locally in response to specific stimuli. RNA binding proteins whose mutations have been linked to several neurological disorders have been localised to granules found in neurons. It is tempting to speculate that mutant RNA binding proteins in these granules accumulate and become converted to irreversible toxic aggregates over time.

Aggregates contain proteins and RNA

Protein aggregation is a hallmark of many neurodegenerative diseases. They are characterised by an irreversible accumulation of mutant proteins that are toxic and impair neuronal functions. Age-associated diseases such as Alzheimer's disease involve protein misfolding and propagation of misfolded proteins. Mutations in proteins that bind RNA have been implicated in diseases such as amyotrophic lateral sclerosis, spinal muscular atrophy, and fragile X syndrome. Normally, granules formed inside cells are reversible protein-RNA assemblies comprised of RNA associated with the



Naoko Tanese, PhD, Associate Dean for Biomedical Sciences, and Director, Sackler Institute of Graduate Biomedical Sciences

protein synthesis machinery and RNA binding proteins. Mutant RNA binding proteins, however, show altered biophysical properties. They have increased propensity to interact with one another and affect the formation and function of the granules. At high concentrations, mutant RNA binding proteins may contribute to the formation of an irreversible toxic aggregate seed that triggers cell death.

Potential role of HD protein in RNA metabolism

Our lab reported a new role for the normal HTT protein in the transport of RNA and maintenance of RNA granules in neurons^{1,2}. We found HTT protein to co-localize and co-traffic with RNA

expressed in neurons. The involvement of HTT in the regulation of RNA could explain the specific pattern of cell loss and symptoms seen in HD. In the presence of mutant HTT, select groups of RNA may be more adversely affected over other RNA. An emerging body of evidence suggests regulated transport of select RNA and local synthesis of proteins from the RNA play a critical role in establishing connectivity between neurons. Our findings implicate normal HTT in these important dynamic neuronal processes. We hypothesise that HTT protein associates with a subset of RNA and regulate their fate in response to synaptic activity. It is possible that mutant HTT perturbs the process in some way, contributing to a loss of cellular homeostasis and disease pathogenesis. Thus, like other RNA binding proteins linked to neurodegenerative diseases, HTT may play a role in RNA metabolism in neurons and share mechanisms and common pathways that lead to their death. Identification and characterisation of RNA bound and regulated by normal and mutant HTT will help to uncover underlying molecular mechanisms. Interestingly, our lab discovered that HTT protein binds its own RNA³, suggesting a mechanism of self-regulation that may go awry in cells harbouring a mutation in the HTT gene.

Therapeutic strategies to treat HD

Since the gene that causes HD was discovered more than two decades ago, scientists around the world have invested monumental time and effort towards the development of therapies

and cures for HD, which has been incredibly challenging. Therapeutic approaches that show most promise to date involve lowering the levels of mutant HTT RNA and protein in affected cells^{4,5}. This may be achieved by advanced technologies developed to silence genes. Most patients have one normal copy and one mutant copy of the HTT gene. Normal HTT is required for proper maintenance of neurons. Although selective silencing of the mutant HTT gene is desirable, this is difficult to achieve because normal and mutant genes are very similar in their DNA sequence. However, even partial silencing of mutant HTT (accompanied by partial silencing of normal HTT) seems to have beneficial effects in mouse models of HD⁶. Such therapeutic approaches are being pursued in hopes of delaying the onset and progression of the disease in patients.

Disruption of irreversible aggregates may be another way to slow or reverse disease progression. A new study reports the formation of RNA aggregates (termed RNA foci) in cells that accumulate RNA containing expanded repeat sequences⁷. The RNA was shown to aggregate when the repeat expansion reached a certain threshold. The resulting RNA foci changed properties from liquid to that resembling gelatine. The study suggests that gelatine-like assemblies are similar to aggregates associated with HD. Moreover, designing chemicals that disrupt the foci may be another avenue for effective therapy to treat this incurable disease.

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Understanding speech and language disorders

OAG Editor Laura Evans talks to NIDCD's Deputy Director Dr. Judith Cooper about the research strides being made in speech and language disorders

The National Institute on Deafness and Other Communication Disorders (NIDCD), part of the National Institutes of Health (NIH), reports that nearly 1 in 12 children ages 3 to 17 has a disorder that is related to voice, speech, language or swallowing. As defined by the NIDCD, a childhood communication disorder can include a child's voice that may be too weak, hoarse or strained; how a child speaks; problems making speech sounds; or problems with how a child learns, understands and uses words or sentences.

Statistics from 2015 revealed that nearly 8% of children between 3 and 17 years experienced a communication or swallowing disorder within a 12-month period. Among those, 55% of children received treatment during the same 12-month period. It was reported that 5% had speech problems, 3.3% of children had language problems, and 1.4% had a problem with their voice.

In order to gain a better understanding of communication disorders in children as well as adults, Editor Laura Evans speaks to Dr. Judith Cooper, Deputy Director of the NIDCD, to shed further light on research in this area and the challenges that arise.

"Speech and language disorders can occur in both children and adults throughout the life span. With children, if you're talking about speech disorders, that term usually refers to difficulty pronouncing speech sounds. There may be a problem in articulating or forming consonants and vowels in the language," Dr. Cooper explains. "Some children have such severe problems that they are literally unintelligible, which means they are talking but you can't understand what they are saying."

"Adults can also have speech disorders. These are usually the result of some sort of neurological event,

perhaps a brain injury, stroke, or Parkinson's disease. Usually these adults had normal speech up until they had the neurological problem, but then find that they have difficulty speaking and being understood.

"Another speech disorder found in both children and adults is stuttering, or problems with fluent speech."

"Language disorders are problems in comprehending (understanding) or using words and sentences. With children, what you may see is a child who is very slow to talk, with delays in first words, or they've got single words but they don't seem to be able to put the words together, or they put the words together but their grammar or syntax is off."

"For adults, language problems typically occur, again like speech problems, as a result of stroke or another kind of neurological problem."

In order to gain further knowledge and develop treatments to help people living with speech and language disorders, research plays a vital role. As Dr. Cooper explains, research is improving the process of early identification of children who are at risk of developing these disorders, and lessening problems that could arise.

"For children who have speech and language disorders, sometimes it's hard to tell them apart from other children until speech and language should be appearing, at which time it becomes really hard to understand them compared to their peers, or they don't seem to be doing very well in language," she says.

"We do have speech and language treatments: for young children, preschoolers, and all the way up to adults. What many of our treatment studies show us is that one treatment doesn't solve the problem for all

individuals. So what research is trying to address is what kind of treatment works for what kind of profile for that disorder, and how often do they need the intervention. These are questions we can only answer through rigorous research.”

The role of research

According to Dr. Cooper, the mission of the NIDCD is to improve the lives of people with communication disorders. Through both basic and clinical research, the Institute is continually looking to improve methods of identifying, treating, and preventing communication disorders, all with an ultimate goal of helping people with these speech and language disorders and their families.

“We make a huge effort to get the results of our research out to the public, as well as to healthcare providers and clinicians,” says Dr. Cooper. “We do that through the [NIDCD public website](#), on which we have publications that are developed to convey research results. Many of our staff go out to scientific meetings and to professional organisation meetings to talk about the findings of research.”

The Institute’s commitment to research and delivering the results to patients and healthcare providers is crucial. Challenges come with any type of research, however, and communication disorder research is no different. Dr. Cooper says that there are key challenges in this area of research, and she underlines the importance of understanding what works best for each individual.

“One challenge for the future is individualised intervention: How do we figure out what’s going to work best for a particular individual with a particular type of disorder? For the longest time, our studies would take a group of people with similar disorders and treat them similarly. More individualised intervention is the way of the future.”

Finding populations and individuals to take part in research can also be a problem, as there are more people who don’t have communication disorders than do. Dr. Cooper notes, “Researchers have rigorous cri-

teria about the kind of population they are studying in a particular research project, and one of the challenges is for investigators to find sufficient numbers of individuals who are willing to participate. Many times, our investigators have to involve multiple sites, multiple hospitals, and multiple collaborations, and that’s often a challenge.

“Another challenge is making our findings relevant to as diverse a population as possible,” she adds. “For a long time, many less well studied populations were not included in some of our research. Thus, there was limited relevance of our findings to individuals not included, for example, those from low socio-economic status or individuals from diverse ethnic or racial groups. Expanding the diversity of the populations included in our research is a priority.

“This is also the case for particular populations with communication impairments. For example, much of the research in communication and autism was previously focused on individuals who were at the higher end of the autism spectrum. So who got left behind? Minimally verbal children with autism. Now our Institute has been encouraging and trying to push forward the need for that kind of research, and we are certainly making some progress.”

The NIDCD sponsors a broad range of research to better understand the development of speech and language disorders, improve diagnostic capabilities, and fine-tune more effective treatments. ■

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Specific language impairment: what do we know?

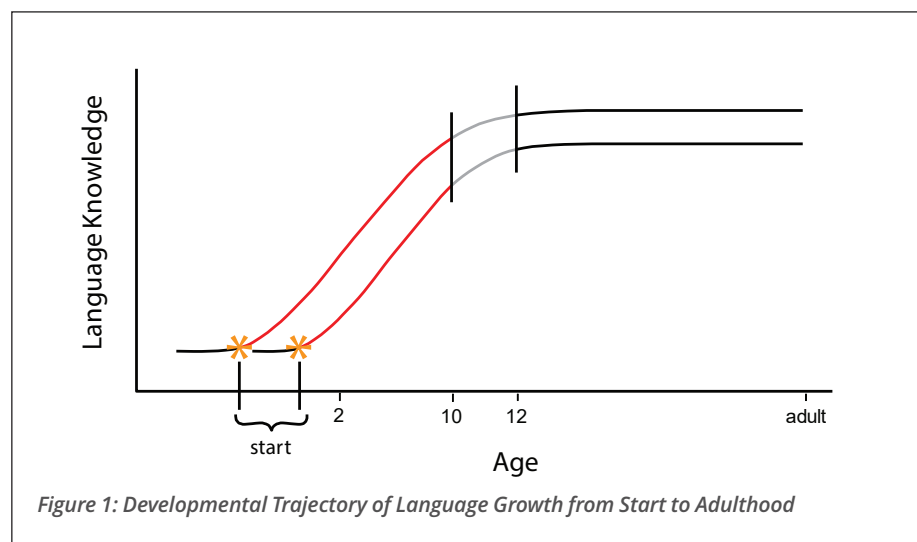
Mabel L Rice, University of Kansas details how the language of children with specific language impairment differs from typical children

A recent paper in this publication introduced the condition of Specific Language Impairment (SLI) as a largely unrecognised yet high impact common disorder of childhood (7-10% of children) that persists into adulthood and warrants further consideration by public health experts. SLI is a language disorder that delays the mastery of language skills in children who have no hearing loss or other developmental delays. Recent studies reveal the ways in which language development in children with SLI is not the same as unaffected children, yet also shows many of the same strengths.

These 3 findings are crucial to understanding the differences and similarities across the age span of 1 to 20 years of age. To sort this out, we need to consider the developmental arc of children's acquisition of language, from first words as toddlers, through childhood, and into adulthood. We also need to consider different dimensions of language; single words appear first, followed by simple sentences that adhere to grammatical rules. Some features of the adult grammar are relatively late-appearing in English-speaking children and those features are especially late for children with SLI.

Finding 1: Children with SLI are likely to be late language learners

Most children start producing words between 1 and 2 years of age, and then follow an accelerated rate of lan-



guage acquisition. As shown in Figure 1, children with SLI can be delayed by 1 or even 2 years in this early start-up period. Studies of preschool children report that the language of 5-year-old children with SLI resembles that of 3-year-old typically developing children, a notable delay at a time of rapid change. Yet when their language system begins to grow, it does so at a rate and pattern of change much like that of younger children. Children with SLI seem prepared to learn language in much the same way as other children, only with a delayed start. Because the rate and pattern of change in children with SLI parallels that of unaffected children, they are not likely to 'catch up' to their age peers. Yet when children with SLI reach preadolescence they, like typically developing children, slow their rate of language acquisition and then level off into adulthood, the stable end-state for much of language development¹.

Finding 2: Delayed vocabulary development can follow the pattern of late start + similar growth trajectories

Not all children with SLI have vocabulary deficits beyond the preschool years, but if so, the pattern holds over many years. Vocabulary growth is shown in Figure 2². This figure charts children's understanding of words, from 4 to 20 years of age, in a study that tested the same children annually. The SLI group is at the bottom 15% for their age and, in this study, the typical group is in the top 15%. At 4 years the SLI children, on average, know fewer words than children at higher levels for their age. This is not surprising; what is of interest is that the children at the low end learn new words at the same rate over time as the comparison group, but they don't close the gap. Instead, for both groups the rate of new word learning markedly slows with age, beginning at

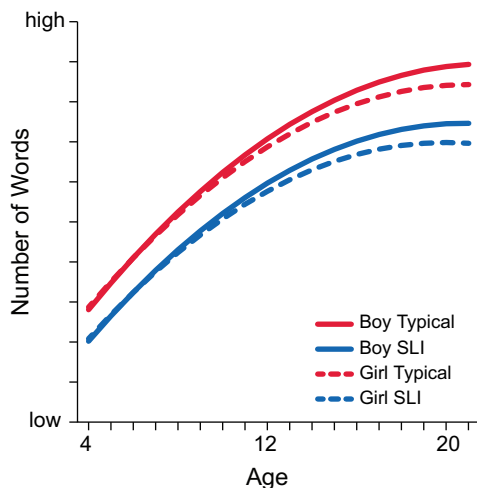


Figure 2: Growth of Word Comprehension from Childhood to Adulthood

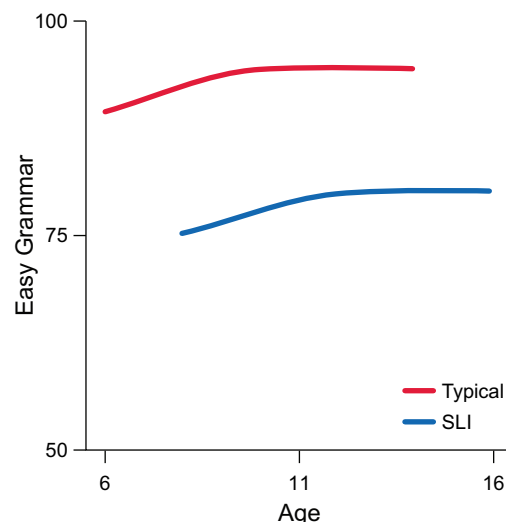


Figure 3: SLI Children's Judgment of Omitted Tense and Agreement Markers in Childhood

10-12 years of age and maintaining a slower rate into adulthood. Although before 4 years of age girls tend to have larger vocabularies than boys, this study found girls to have a slower rate of word acquisition than boys in adolescence, which left a marked disadvantage for girls with lower levels of vocabulary in the crucial time of education for preparation into the work place or higher education.

Finding 3: Tense and agreement marking on verbs is a grammar requirement likely to be difficult for children with SLI

This is evident in the use of forms of auxiliary or copula BE, as in "He is happy" and "Are the girls here?" as well as Auxiliary DO, as in "Does he want a cookie?" past tense, as in "Patsy walked home" and third person singular, as in "He wants a cookie." The persistent problem is that children with SLI, on average, omit these parts of the sentence as if the requirement were optional instead of obligatory. Figure 3 shows how persistent this tendency is in children with SLI³. As expected, between the ages of 6 and 16 years typically developing children recognise in judgement tasks that omission of

these parts of the grammar render a sentence ungrammatical. Even at 6 years this is an easy task. Yet children with SLI, on average, persist in considering omissions as optional and OK for grammar. It is as if they are stuck with an immature form of the grammar into adolescence.

Interpretation: SLI is a persistent language disorder that is evident early in development and has many similarities to younger language profiles with steady gains in language, levelling off in adolescence. This makes it likely that a child with SLI will become an adult with weak language skills, particularly in some, but not all, parts of the grammar. Much of the weakness in language can be hidden under compensatory social skills, and thereby goes undetected as a likely contributor to poor reading skills or avoidance of social interactions in adolescents and adults. Current studies investigate genetic influences on the causal pathways, as inherited language abilities can drive the strong language growth trajectories, yet selective inherited differences operative at key times could account for persistent and unresolved delays¹.

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Image-guided surgery as an emerging treatment for lung cancer

Sumith A Kularatne, Vice President of Research & Development at On Target Laboratories discusses the scope of image-guided surgery in treating lung cancer

Lung cancer remains one of the major cause of cancer related death worldwide, resulting in over 1.4 million deaths per year. Treatment for lung cancer has been estimated at \$20 billion per year, in the US. Smoking (85%), genetic factors (8%), exposure to radon gas, asbestos, polluted air, and second-hand smoking can be considered as the major causes of lung cancer. Based on morphology of cancer cells, lung cancer has been classified into small-cell lung cancer and non-small-cell lung cancer. Non-small-cell lung cancer can further subdivided into adenocarcinoma, squamous-cell carcinoma and large-cell carcinoma subtypes. Lung cancer is diagnosed by a chest X-ray or computed tomography (CT) scans followed by a biopsy. Depending on the stage of the disease, treatment of non-small-cell lung cancer commonly involves surgery, chemotherapy, and/or radiotherapy whereas treatment of small cell lung cancer is more often limited to chemotherapy and radiotherapy.

Surgery plays an important role as a therapeutic method in non-small-cell lung cancer and over 70% of stage I and II non-small-cell lung cancer patients undergo surgery. Therefore, to accomplish optimal surgical resection of the tumor, it is important for the surgeon to locate and identify tumor margins accurately. Since surgery may be the primary therapeutic modality for substantial proportion of non-small-cell lung cancer patients, it is imperative that all cancerous tissues are excised with negative margins.

On the other hand, since the majority of the lung cancer patients are smokers, it may also be important that to leave non-cancerous lung tissue intact. The lymph node status is also important to determine the therapeutic options for the lung cancer patients. For example, metastasis to the mediastinal lymph nodes would be an indicator of not to proceed with excisional therapeutic surgery.

Unfortunately, this can only be seen once the thoracic cavity is open and this process can delay the needed chemotherapy. Moreover, spread to the lymph nodes determines adjuvant therapy. It is important to note that lymph nodes harbor metastatic cancer cells often feel and look normal, and may not detect by pre-operative techniques like X-ray or CT scans. In addition to that, those pre-operative imaging techniques will not provide real time information during surgery as they are confined to static images.

Intra-operative pathological procedures such as a frozen section are time consuming and often miss tumors due to miss-sampling, as well as poor tissue preparation, etc. Thus, there are imperative medical demands to develop new innovative technologies that help to remove a tumor completely with negative margins, identify micro-metastases including lymph nodes harboring metastatic cancer cells and leave intact non-cancerous lung tissues.

Image-guided treatment

Image-guided surgery is an emerging technique that aids surgeons to identify malignant tissues accurately and surgically remove tumors without compromising healthy tissues. However, one of the inherent challenges in the field is to develop imaging agents that are specific and sensitive for the tumor cells, particularly occult lesions that would not have been identified by usual techniques. While indocyanine green (ICG), a FDA approved near infrared (NIR) agent, has been used in image-guided surgeries for cancer, and it has been found to have significant limitations with respect to sensitivity and specificity, due to non-targeted nature of the molecule. Therefore, NIR agents that selectively label lung cancer tissues are currently under clinical development. These agents either target a receptor that overexpress on lung cancer cells or an enzyme or cell signaling pathway that uniquely present in lung cancer cells.



Real-time visualisation of malignant masses using cancer cell targeted-NIR agents will not only benefit to remove primary lung tumor masses with complete negative margins but also lymph nodes harboring metastatic tumor cells. Moreover, fluorescence imaging using these agents can aid in the surgical decision to conserve lung function by removing only the diseased tumor tissue rather than lobectomy or pneumonectomy.

Sumith A. Kularatne, PhD, is the Vice President of Research & Development at OTL. He has pioneer experience in drug designing on both small molecule ligands- and antibody-targeted drugs. Dr. Kularatne's scientific efforts have resulted in 6 drug candidate in human clinical trials with 3 different companies, over 50 US and foreign issued/pending patents and over 30 peer-reviewed publications. He has given multiple invited seminars/lectures in prestigious conferences as well as in multiple institutes and has received several

international and national awards including phase I and phase II NIH SBIR grant awards for over €2m. ■



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Drug development for cancer and inflammatory disease

Sumith A Kularatne, Vice President of Research and Development at On Target Laboratories shares the research strides he has made in drug development

"Men are haunted by the vastness of eternity. And so we ask ourselves: will our actions echo across the centuries? Will strangers hear our names long after we are gone and wonder who we were, how bravely we fought, how fiercely we loved?" – Odysseus (Troy).

Sumith A. Kularatne, Ph.D., is the Vice President of Research & Development at, On Target Laboratories, LLC (OTL), West Lafayette, IN (March 2012 – present). Dr. Kularatne is a world-class researcher and problem solver within the field of drug design and development for cancer and inflammatory disease. In fact, his distinctive and unparalleled approach to solve the problems associated with the diagnosis and treatment of cancer has been nothing short of unique and groundbreaking.

Dr. Kularatne says that "health holds a very important role in one's life, as President Thomas Jefferson said. Liberty is to the collective body, what health is to every individual body... Without health no pleasure can be tasted by man... without liberty, no happiness can be enjoyed by society".

Therefore, Dr. Kularatne uses his diverse set of skills, ranging from medicinal chemistry, organic chemistry, cancer biology, biochemistry, molecular biology, protein and antibody engineering, and animal model development for drug testing that



enables him to solve problems from a multidisciplinary approach and to discover better therapies with higher efficacy. Throughout his research career, Dr. Kularatne has been dedicated to developing targeted-imaging agents, diagnostic methods, and – therapeutic agents for cancers such as prostate, ovarian, lung, breast, and leukaemia and their metastatic disease and inflammatory diseases, such as rheumatoid arthritis and heart disease.

Research strides

Under his guidance, OTL has developed a strong pipeline for several types of cancer and inflammatory diseases. OTL38, a folate receptor (FR)-targeted near infrared (NIR) dye, has been proven safe in a phase I trial and effective in a completed phase II

clinical trial for ovarian cancer. A phase II trial for lung cancer and a phase III trial for ovarian cancer began in summer 2017. The same NIR dye has been conjugated to additional ligands targeting receptors on prostate (OTL78: PSMA-targeted NIR agent), colon (OTL338: CA-IX-targeted NIR agent), and pancreatic (OTL81: CCK2R-Targeted NIR agent) cancers. These ligands can also be conjugated to a photodynamic therapeutic (PDT) agent, giving surgeons the option to visualize and 'burn' targeted lesions using the same light source and camera. A lead folate- PDT compound (OTL228) has been identified with others to follow.

He pursued his postdoctoral studies in molecular biology and biomedicines with Peter G. Schultz, CEO and Professor of Chemistry at The Scripps

Research Institute (TSRI), San Diego, CA (Dec 2009-Feb 2012). Dr. Schultz was the founder and former director of GNF, and is the founding director of the California Institute for Biomedical Research (Calibr) La Jolla, CA. Dr. Kularatne's projects at TSRI focused on selective diminishing of primary tumor masses, metastatic cancers, and cancer stem cells using antibody drug conjugates (ADCs) or using bispecific antibodies (antibody-dependent cell-mediated cytotoxicity or ADCC).

“Innovation is a process that starts from coming up with a new idea to launching a new product in the market.” Dr Sumith A Kularatne.

Dr. Kularatne earned his Ph.D. in organic/medicinal chemistry from Purdue University, West Lafayette, IN (Dec 2005-Dec 2009), conducting research under the guidance of Philip S. Low, the Ralph C. Corley Distinguished Professor of Chemistry and Director of the Purdue Center for Drug Discovery at Purdue University. Dr. Low is also the co-founder and CSO of both Endocyte and On Target Laboratories. Dr. Kularatne's research at Purdue University concentrated on small molecule-targeted drugs for cancers and inflammatory diseases.

His scientific efforts have resulted in 6 drug candidate in human clinical trials with multiple companies, over 50 US and foreign issued/pending patents and over 30 peer-reviewed publications. He has given multiple invited seminars/lectures in prestigious conferences such as “Gordon Research Conference” on “Drug Carriers in Medicine & Biology”, as well as in national and international conferences, universities, and industries. Dr. Kularatne's scientific involvements have also led to several international

and national awards including, “SBIR Phase II Grant Award for Non-Small Cell Lung Cancer Research (2017)”, “Distinguished Partners in Hope Award for OTL for fueling innovation, and providing hope to lung cancer patients (2016)”, “Innovation Corps at NIH program for SBIR Award for Drug Development for Non-Small Cell Lung Cancer (2016)”, “SBIR Phase I Grant Award for Non-Small Cell Lung Cancer Research (2014)”, “AAPS Postdoctoral Fellow Award sponsored by Merck (2012) for CXCR4-targeted antibody drug conjugates for metastatic cancers”, “the Skaggs Postdoctoral Fellow Award (2010)”, “AAPS Graduate Student Award in Biotechnology, sponsored by Pfizer (2009) for PSMA-targeted drugs for prostate cancer, AAPS Graduate Student Symposium sponsored by Eli Lilly (2009) for PSMA-targeted drugs for prostate cancer, Delano Maggard, Jr. graduate research award (2005)”, ACS recognition Chemist of the year (2004), E. A. Talaty fellowship (2003) and the B. L. Parker Endowed fellowship (2002). He is an invited member of multiple honorary societies including Phi Kappa Phi (NSF), National Society of Collegiate Scholars, and Beta Phi Upsilon. He is also an invited peer reviewer for multiple scientific journals including Journal of Organic Chemistry, Molecular Pharmaceutics, Journal of Medical Case Reports, Nature Publishing group, and Drug Delivery.

Looking back on his 11 year career, Dr. Kularatne said that “I am fortunate and blessed to develop drugs that can possibly make a tremendous impact on human life, especially those who are suffering from cancer and their loved one”. He believes what Michael Jordan said “talent wins games, but teamwork and intelligence wins championships”. Dr. Kularatne stated that “I want to



emphasis that all the accomplishments I have been involved with were a team effort. I have always been around a great group of people committed to work in cohesion with one another. I have been guided by great leaders and mentors. I have great parents, family and friends who support me unconditionally. So, I feel I was prepared by mentors and family to accomplish great things as mentioned by Sun Tzu, The Art of War, 400 B.C. “Every battle is won before it is fought”.

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Childhood cancer trends: how to interpret new findings

Dr Eva Steliarova, Scientist at IARC's Section of Cancer Surveillance explains how research results can be used to reduce the burden of cancer in children

IARC's international study on the incidence of cancer in childhood found a global increase of 13% in childhood cancer between 2001-2010 compared to the 1980s. The percentage increase compares the incidence rates of 124 per million for the earlier period and 141 per million for the more recent one. With the exception of sub-Saharan Africa, the increase affected all the world regions we studied, and ranged between 3% (Central America and Caribbean) and 30% (South-east Asia). What could this increase be attributed to?

The challenge of data collection

Although the 2 studies used comparable methods and provided the best estimates of incidence for their respective periods, the covered populations differed. Data were not available for some areas included in the earlier study, while new areas were included in the more recent statistics.

It was important to ensure that data collected in different countries are comparable, so that we can draw conclusions from the observed differences in incidence rates. The established data flow system, motivated staff in cancer registries around the world, a set of international standards and extensive communication between the contributors were required for conducting this study. Our main aim was to define the level of cancer occurrence in the young populations, the most important determinant for cancer control planning and for further research into the causes of cancer in this young population. The produced information does not suffice, however, to explain the causes of the observed patterns. Further focused investigations are required in this direction.

The role of improved diagnosis

Future detailed examination of the incidence trends for specific cancer types could indicate the role of improved diagnosis. For example, a rise in the CNS tumours could be attributed to the implementation of magnetic resonance imaging (MRI) in the 1980s in high-resource countries, and their gradual uptake in less privileged areas. The lack of CNS tumours as well as sophisticated imaging technology on the African continent supports indirectly the role of diagnosis in the temporal trends. Over the time, diagnoses are increasingly based on molecular and genetic analyses, new entities are being recognised and changes in tumours classification proposed. More tumours may be counted as malignant. The novel imaging techniques may detect tumours earlier in life, which would contribute to higher rates within the childhood age-range. On the other hand, the increase in incidence rates was seen in the areas with advanced, as well as with developing diagnostic facilities, which may suggest that the improved diagnosis does not explain the observed increase entirely.

Improved awareness and referral system

More cancers may be detected also because of improved awareness among primary healthcare providers and more frequent referral of suspected cancers for correct diagnosis and treatment. The role of professional associations such as the [International Society of Paediatric Oncology](#) (SIOP), as well as charitable actions of patients' families may drive a better or faster access to diagnostic facilities.

Registration of diagnosed cases might have improved

with the accumulation of local expertise and maturation of international cooperation. A legal requirement to register (childhood) cancer cases, instituted in numerous registration areas during the 3 decades would definitely enhance the registration completeness.

A role of exposure to risk factors?

The data assembled in our study cannot confirm or refute an increased exposure to various risk factors of childhood cancer identified in other studies. The early life onset and the association of some childhood cancers with a number of inherited syndromes may explain some 5% of cancers in children. Multiple external risk factors have also been examined. While ionising radiation from atomic bombs, industrial accidents or medical interventions may cause leukaemia, thyroid and possibly other childhood cancers, the levels and opportunities of these exposures are relatively limited, as is the proportion of cases due to radiation. Some wide-spread viruses (Epstein-Barr or Human immunodeficiency virus, HIV) together with other co-factors may also lead to cancer development, such as Burkitt lymphoma or Kaposi sarcoma, both highly prevalent in sub-Saharan Africa. Environmental pollution, exposure to pesticides or other carcinogens and some dietary constituents of children or their parents were also associated with childhood cancer in some studies, but not in others. The barriers to a better knowledge of the causes lie in the low frequency of cancer in children, difficulty of accurate exposure assessment, as well as in isolation of potential risk factors from the multitude of simultaneous exposures.

Geographical and ethnic differences in childhood cancer occurrence

Our large international study characterises the geographical and ethnic differences in childhood cancer occurrence and suggests possible associations worthy of further study. One example may be the high relative incidence of childhood leukaemia in South-East Asia, the area which is also known for the wide-spread use of pesticides in agriculture. Another illustration is the drop in the incidence rates in sub-Saharan Africa, at least in part attributed to a reduction of HIV infection load through antiretroviral therapy in the exposed childhood population. This observation implies that external factors may be involved in childhood cancer development and also that preventive measures may result in a reduction of incidence.

Cancer prevention and control is a recognised priority by the WHO¹ and integrates continued surveillance to help with planning childhood cancer care. Our study also serves as a springboard for detection of associations which, if confirmed, may lead to taking preventive actions and possibly reducing childhood cancer incidence in the future.

The International Agency for Research on Cancer (IARC) the specialised agency of the WHO, is coordinating the International Incidence of Childhood Cancer study in collaboration with [International Association of Cancer Registries](#) (IACR) and with a financial support of [The Union for International Cancer Control](#) (UICC). The first bulk of results of the study were released online on the occasion of the International Childhood Cancer Day on 15 February 2017 and at <http://iicc.iarc.fr/> and they will be followed by a printed publication later in 2017 with a complete background on data sources and methods. An overview paper summarising and interpreting the main findings by world regions for period 2001-2010 was published in June by The Lancet Oncology (<http://www.sciencedirect.com/science/article/pii/S1470204517301869>). ■

About the author

Dr Eva Steliarova is a senior scientist, at IARC's Section of Cancer Surveillance. She coordinates the work on the third volume of the International Incidence of Childhood Cancer (IICC-3), presented at <http://iicc.iarc.fr/> and other international studies of cancer in children. She relies on active collaboration of hundreds of data contributors, the international boards of advisors and editors, as well as the support by her IARC colleagues.

¹ http://apps.who.int/gb/ebwha/pdf_files/WHA70/A70_R12-en.pdf

International Agency for Research on Cancer



Dr Eva Steliarova Scientist

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Photodynamic Therapy – radiotherapy for the 21st Century

Photodynamic Therapy is a treatment that combines a photosensitizing drug, visible light and oxygen to kill cancer cells. Professor Eli Glatstein explains

For this treatment to have a biological impact, these 3 factors must be together at the same time, in the same place. Because PDT depends on visible light, the treatment naturally spares critical normal tissues that lie beneath the cancer. Red (or near-infrared) light is the most penetrating in human tissues. This can be simply illustrated by the classic ‘experiment’ of placing one’s fingers together over the head of a flashlight turned on; only red light gets through where the fingers come together. With recent innovations in diode laser and fibre-optic technologies, it is now relatively straightforward to deliver light of a suitable wavelength to match the desired depth of tissue penetration and the absorption spectrum of the photosensitiser.

“In practical terms, the only real limitation to the application of PDT for the treatment of cancer is the imagination required to get the light where it is needed. For this purpose, treatment at the time of surgery provides an opportunity to deliver light internally where the cancer is most likely to recur following removal.”

When the photosensitising agent is administered IV, it goes ubiquitously into virtually all cells and tissues. However, most tumour tissues appear to take longer to clear the photosensitiser, leading to a modest (~2-3 fold) tumour selectivity. Porfimer sodium is the only intravenous photosensitiser

that is currently FDA approved for cancer treatment in the USA. In the EU, Temoporfin is also approved for cancer treatment, but both photosensitisers are retained in normal skin and require the patient to avoid bright (sun) light for about 6 weeks after drug delivery. Nevertheless, these photosensitisers have been successfully used to treat a wide variety of tumours, including head and neck, lung, oesophageal, bladder, cervical and skin cancers, as well as malignant pleural mesothelioma. This selectivity can be enhanced by encapsulating the photosensitiser in a nanoparticle that targets molecular abnormalities specific to tumours. Verteporfin, an early version nanoparticle photosensitiser has been highly successful at treating age related (wet) macular degeneration and is currently in clinical trials as a treatment for prostate and pancreatic cancers.

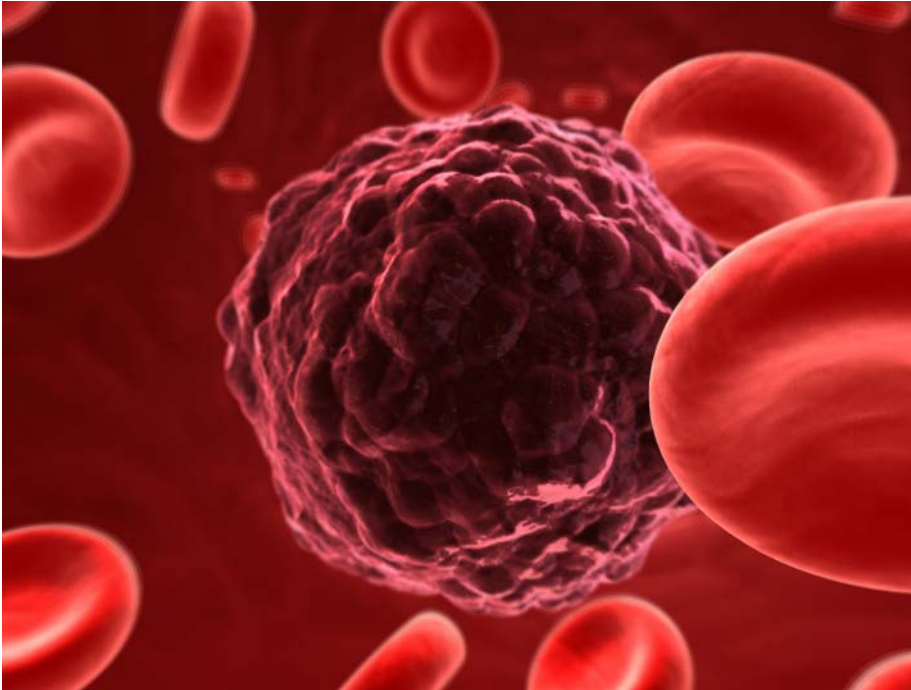
Except at specialised centres of excellence, most of the PDT throughout the world is aimed at relatively small non-melanomatous skin cancers or GI surface lesions that can be approached by endoscopic techniques. At Penn, we are using PDT to ‘light up’ the entire pleural cavity at the time of surgical resection for patients who have malignant miliary seeding of the pleural surface, which is generally considered an incurable condition. With this approach, we have extended the median survival of patients with advanced stage malignant pleural



mesothelioma to more than 3 years (from 12-18 months) while allowing a surgical procedure that spares the underlying normal lung.

Advantages of PDT

While PDT is nonionising radiation therapy, this treatment primarily tar-



gets intracellular membrane structures such as mitochondria and lysosomes. Unlike ionising X-ray therapy, DNA does not appear to be the target for PDT, so that PDT does not induce new mutations into cancers during treatment. PDT also kills cancer cells through different mechanisms than traditional chemotherapy. Thus, PDT's advantages are that it can spare normal tissues far better than other forms of cancer treatment and, because DNA is not its target, treatment induced cancer is unlikely to occur. Moreover, techniques to accurately measure light and photosensitiser in real time can even provide the ability to continuously readapt the treatment either before or even during an individual treatment session to further optimise treatment outcomes. Combined with targeted photosensitisers, PDT presents a unique opportunity for a more personalised, rational approach to cancer therapy.

Limitations of PDT

In practical terms, the only real limitation to the application of PDT for the treatment of cancer is the imagination required to get the light where it is needed. For this purpose, treatment at the time of surgery provides an opportunity to deliver light internally where the cancer is most likely to recur following removal. Relatively simple modifications can be used to avoid unintentional skin burns during surgery, such as using optical filters on the operating room lights and making sure to cover all of the patient's skin with sterile drapes/towels. In addition, light can be introduced directly into a tumour mass by interstitial techniques. This means inserting fibre-optic delivery devices directly into a tumour mass through sterile techniques similar to those that have been employed for brachytherapy, a form of ionising radiation therapy in which radioactive sources are introduced

directly into tumours. For PDT, instead of inserting radioactive isotopes, fibre-optics are used to deliver light from an appropriate laser source. This method has been used to successfully treat head and neck, prostate and pancreatic cancers, but could extend to assist the minimally invasive treatment of brain, breast, lung, bladder and gastrointestinal cancers. Thus, PDT is a critical weapon in the war on cancer. Like all cancer therapies, PDT should not be considered as "the" answer for cancer treatment but rather as an important tool in the medical armamentarium that can be adapted to an individual's cancer to provide personally optimised cancer therapy.



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The dilemma of over diagnosis of pancreatic cysts

Dr. Annabelle L. Fonseca et al explain the problems created by current medical guidelines for diagnosing pancreatic cysts

More than 2% of abdominal computed tomography (CT) scans will show a cyst in the pancreas. What to do about these cysts can sometimes leave us in a quandary.

Intraductal papillary mucinous neoplasms (IPMNs) are the most common type of pancreatic cyst that may harbour cancer or develop into cancer. This is a relatively new disease, first identified in 1982, and while our approach to these tumours has evolved since then, many patients still receive unnecessary treatment and we clearly still have a long way to go.

What are IPMNs?

IPMNs are cystic tumours that grow within the pancreatic duct and are characterised by the production of thick viscous mucous. The main pancreatic duct runs down the centre of the pancreas and gives off smaller branching ducts. IPMNs arise from either the main pancreatic duct or one of the branching ducts.

With the increasing use of CT scans, IPMNs are being diagnosed more frequently. Because we did not know enough about the natural history of the disease, and because of the terrible prognosis associated with pancreatic cancer, our tendency was to resect most IPMNs.

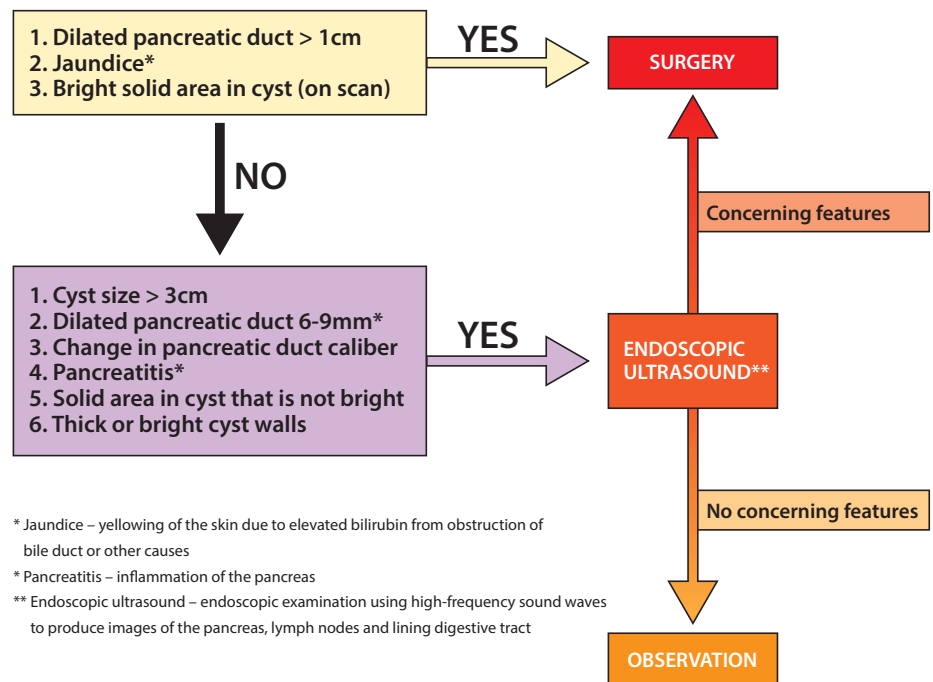


Figure 1: Algorithm for management of IPMNs (based on expert consensus guidelines)

What do we know about IPMNs and the risk of cancer currently?

IPMNs with high grade dysplasia or a cancer component are ideally the ones to remove. Over the past decade we have learnt that specific findings on CT or other imaging can be used to help us with our decision (Figure 1). We currently follow recommendations based on expert consensus to help us decide which of these tumours we should take out. We know that IPMNs that develop from the main duct are at a higher risk of developing into

cancer. We use imaging criteria and clinical findings to decide whether to operate, proceed with additional investigation, or to continue to monitor patients (Figure 2).

Current guidelines have created a dilemma

These guidelines help us to decide which patients would benefit from an operation. However, they also lead to us operating on many patients with IPMNs that would likely have never turned into cancer. The ability of current guidelines to accurately diagnose the

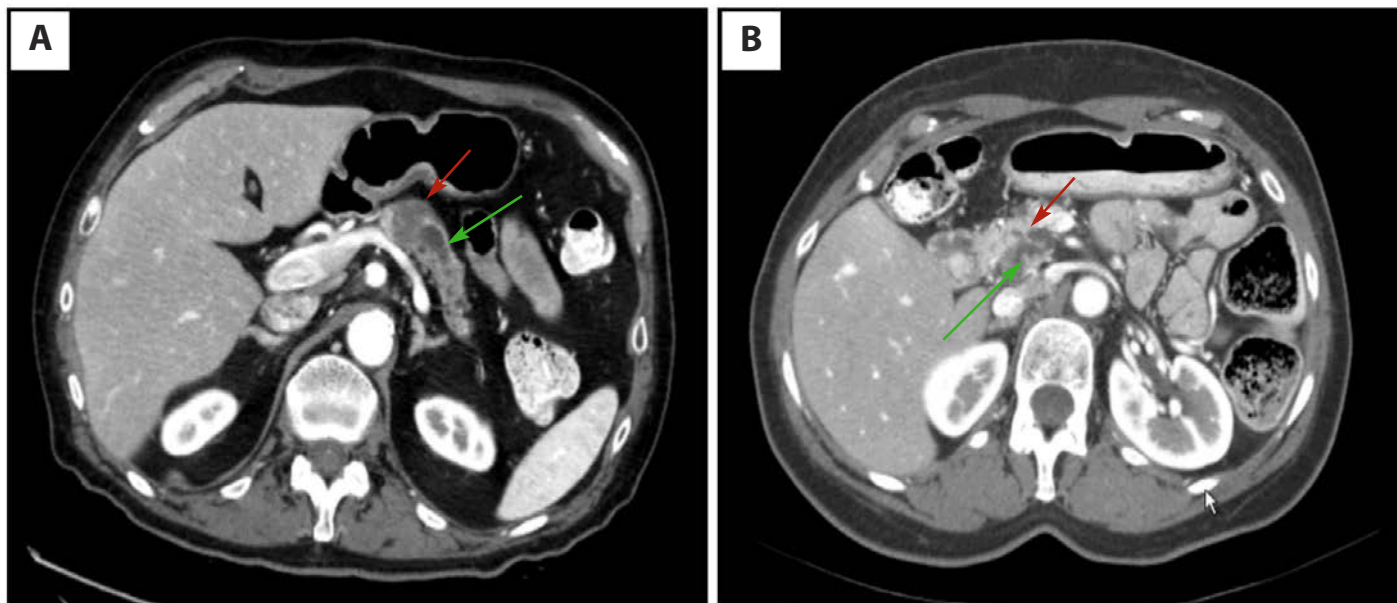


Figure 2: CT scans demonstrate high grade IPMNs (red arrows). Green arrows depict dilated pancreatic duct in (Fig A) and enhancing mural nodule inside IPMN in (Fig B)

presence or absence of high grade dysplasia or cancer ranges from 50-80% according to studies. This means that when we use these guidelines, the proportion of patients that we “over treat” is not insignificant, and we will also miss some patients that do have IPMNs with high grade dysplasia or cancer. This is a problem that we, and several other researchers around the world, are studying.

Current areas of research:

We know that IPMNs are associated with specific genetic mutations. However, these do not necessarily differentiate between those with different risks of becoming cancer. Additionally, this information is usually obtained from the tissue after resection, and this does not help us to decide who needs an operation. Cyst fluid analysis is an exciting area of research, where fluid is obtained during an endoscopic ultrasound, and can then be tested for different biological markers that may

help in our pre-operative decision making. Radiographic imaging is also being studied at a more granular level in the field of radiomics, which is the high throughput analysis of large amounts of quantitative features from imaging. This is based on the hypothesis that the underlying patterns at the genetic and cellular level are reflected in the imaging. Our approach is to integrate all of these sources of information to help us differentiate between these tumours. This data also feeds into mathematical models of tumour growth that may help us to understand the specific mechanisms that contribute to carcinogenesis in IPMNs. In the next article we will describe these exciting areas of research in more detail.

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Environmental health science: reducing the risk

Virginia Guidry and Kimberly Gray from the NIEHS outline how environmental health science can help to identify potential hazards in a child's environment

Now able to crawl and curious to discover all that's around her, little Emma reaches for a dusty toy under the table and, just like any infant would, immediately puts it into her mouth.

What chemicals are in the toy, and is there lead in its worn paint? Do the baby's pyjamas, or perhaps her crib mattress, contain flame retardant chemicals? Has the home been treated with pesticides, now lingering as residue in the dust? Does it matter?

These are the questions that drive environmental health science.

Parents, grandparents, and caregivers have enough to focus on regarding the needs and well-being of their children – making sure they are nourished, clean, and sleeping soundly. The National Institute of Environmental Health Sciences (NIEHS), part of the National Institutes of Health (NIH), funds scientists to methodologically study the silent factors that we often cannot see or smell in a child's environment.

These environmental toxicants can be in the water, food, dust, or air in children's homes, schools, and neighbourhoods. NIEHS-funded scientists determine the likelihood of harm, the sources if unknown, and how to reduce exposure or mitigate potential damage.

Why focus on children?

One thing is clear from NIEHS-funded research – children are more vulnerable to environmental toxicants than adults, particularly while in the womb¹. External substances can interfere with the complex processes of growth and development, which involve rapid cell division and intricate hormonal signals. Additionally, children don't have the mature defense systems that adults do, such as fully functional liver detoxification¹.

Sometimes changes that occur during childhood can have permanent effects².

For example, NIEHS-funded research shows the potential for environmental toxicants to harm brain development. Lead is the best-known example, but there are many others. When pregnant mothers are exposed to high levels of flame retardant chemicals, such as polybrominated diphenyl ethers (PBDEs), their offspring may be more likely to have decreases in IQ, problems with fine motor skills, and symptoms of ADHD³.

Environmental scientists are using MRIs and related technologies to study the brain regions of children exposed to common air pollutants called polycyclic aromatic hydrocarbons (PAHs), which come from fossil fuel combustion⁴. The structural and functional changes they have observed in the brain may explain why exposure to PAHs while in the womb has been linked to lower IQ and symptoms of anxiety, depression, or ADHD^{5, 6}.

Technologies help identify hazards

However, it can be difficult to know what toxicants a child has been exposed to in the womb or as a baby. Some scientists are analysing naturally shed baby teeth to reconstruct early-life exposure to lead and other metals that are incorporated into teeth as a child grows⁷. By comparing exposure information with later diagnoses, the scientists have shown that increased lead uptake, and decreased uptake of the essential nutrients zinc and manganese, may be related to autism⁸.

NIEHS-funded researchers also are developing wearable or mobile technologies to help caregivers recognise hazards in a child's environment. Scientists have designed wearable wristbands that can detect exposure to organic chemicals, such as flame retardants



or pesticides, over the course of a few hours or days⁹. Others are collaborating on an [app](#) that will help children, their parents, or healthcare providers track real-time air quality conditions so that asthma triggers can be avoided.

New programme to study children's health

Fortunately, there is a new, national effort that will allow scientists to study a variety of environmental influences on children's health. In 2016, NIH launched the 7 year Environmental influences on Child Health Outcomes ([ECHO](#)) programme. ECHO is focused on 4 important children's health outcomes: illnesses like asthma in the upper and lower airways, obesity, neurodevelopment, and health around the time of birth. ECHO is pooling resources from many NIH-funded studies to increase researchers' ability to study how a child's environment, from pregnancy through adolescence, may affect the immediate or long term health of our children.

ECHO and NIEHS-funded research will continue to point to ways that we can advance lifelong health by improving the environmental conditions around pregnant women and children. We already know that when air quality improves, children have better lung growth¹⁰ and decreased bronchitis-like symptoms¹¹. Similarly, women at the end of their pregnancies during the 2008 Beijing Olympics had babies with healthier birth weights than women exposed to higher, typical air pollution levels during the same dates in 2007 and 2009¹².

These studies show the potential health benefits of reducing environmental toxicants. These improvements matter – especially for children. ■

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Environmental chemicals: factors for neurodevelopmental disorders?

Pamela Lein, University of California, looks at whether environmental chemicals influence individual risk for the diagnosis of neurodevelopmental disorders

Neurodevelopmental disorders (NDDs) are a group of clinically heterogeneous conditions characterised by impaired growth and development of the brain. These include autism spectrum disorders (ASD), attention-deficit hyperactivity disorder (ADHD), schizophrenia, learning and intellectual disabilities, and sensory impairments. The current prevalence of ASD is estimated to be at least 1.5% of children in developed countries; the worldwide prevalence of ADHD is estimated to be 5.3% of children and adolescents; and learning and intellectual disabilities are more common than ASD and ADHD combined. Considered in the context of the tremendous costs these conditions exact on the affected individual, their families and society, these statistics underscore the urgent need to identify factors that confer risk for NDDs.

Until recently, research on the aetiology of NDDs has focused largely on genetic causes. However, this research has clearly shown that even for ASD, which is considered one of the most heritable of the complex NDDs, single genetic anomalies can account for only a small proportion of cases and, overall, genetic factors seem to account for at most 30-40% of all NDD cases. Such observations have contributed to a paradigm shift such that many NDDs are now largely thought to result from complex gene-environment interactions.

Why do we think environmental factors influence NDD risk?

Compelling evidence in support of an environmental contribution to NDD aetiology includes the rapid increase in the prevalence of ASD and ADHD over the past several decades. This is unlikely to have been caused by evolutionary shifts in the human genome. While some have questioned whether this represents a true increase in the number of affected children, studies to address this question have uniformly concluded that the broadening of diagnostic criteria, increased awareness and improved detection can only partially account for the increased prevalence of NDDs.

Genetic studies also support a role for environmental factors in determining NDD risk. Incomplete monozygotic concordance is a consistent finding in twin studies of both ASD and ADHD, and even in genetic syndromes highly associated with ASD, a significant percentage of individuals carrying the ASD-linked gene do not express autistic phenotypes. More recently, a study of 192 mono- and dizygotic twin pairs, and another of 14,000 children with autism, independently concluded that 50% or more of cases could be attributed to environmental causes. Collectively, these studies are consistent with a model in which environmental factors modify genetic risk to significantly influence not only susceptibility to NDDs, but also the variable expression of phenotypic traits. This model

provides a biologically plausible explanation for both the dramatically increased prevalence and clinical heterogeneity that are characteristic of complex NDDs.

Environmental factors associated with increased NDD risk

Observations of a high incidence of autism associated with congenital rubella were among the first reports demonstrating that an environmental factor could influence NDD risk. Subsequently, prenatal infections were linked to an increased risk for other NDDs, particularly schizophrenia, and the range of non-genetic NDD risk factors was expanded to include intrauterine stresses, increased paternal age, maternal nutrition and metabolic status, and endocrine disruption. The first indication that chemical exposures may also influence NDD risk were reports that in utero exposure to valproic acid or thalidomide during critical periods of development was associated with increased expression of autism-related traits. Subsequent epidemiological studies reported increased NDD risk associated with maternal use of various medications and drugs of abuse, including alcohol, as well as prenatal or early postnatal exposure to diverse environmental chemicals. Environmental chemicals postulated to confer risk for NDDs include legacy chemicals known to be toxic to the developing human nervous system, such as lead, mercury and polychlorinated biphenyls (PCBs), as



well as more contemporary contaminants such as pesticides, including organophosphorus (OP) and organochlorine (OC) pesticides, neonicotinoids and pyrethroids, flame retardants including the polybrominated diphenyl ethers (PBDEs), plasticisers such as phthalates and bisphenol A, and complex environmental mixtures such as air pollution and cigarette smoke.

Current challenges in the field, and a potential path forward

Current epidemiological data support the hypothesis that chemicals in the human environment contribute significantly to NDD aetiology, but also highlight the difficulty of establishing causal links between environmental exposures and NDDs. Recent reviews have concluded that, with the possible exception of tobacco and alcohol, there are insufficient numbers of epidemiological studies and/or studies are too limited in scope to either infer causality or to rule out the possibility that specific environmental factors confer NDD risk. The challenges of using epidemiological approaches to identify environmental risk factors include obtaining accurate measures of exposure, particularly for chemicals with short half-lives such as some of the pesticides, phthalates and BPA, controlling for confounding factors, especially socioeconomic stressors that tend to co-vary with environmental exposures, and are known to influence neurodevelopment independent of chemical exposures, and dealing with

multiple exposures, a not insignificant issue in light of reports that 250 environmental chemicals were detected in biological samples from a 2013 representative sample of the United States in the National Health and Nutrition Examination Survey. Epidemiological approaches must also deal with the phenotypic heterogeneity and complex multigene aetiologies that are likely to create a range of sensitivities to environmental factors, which will further mask clear associations between exposure and diagnosis.

To overcome these challenges, it will be necessary to invest resources in basic mechanistic research using experimental models to understand how environmental factors modify genetic predispositions to influence individual susceptibility and/or severity for NDDs. While a number of mechanisms have been proposed to explain gene-environment interactions, one fundamental way in which heritable genetic vulnerabilities can amplify the adverse effects triggered by environmental exposures is if both factors (environmental and heritable) converge to dysregulate the same neurotransmitter, signalling system or neurodevelopmental process during a critical developmental window. Genetic studies have identified convergent molecular mechanisms for many NDDs, which provide a biological framework for developing cell and animal models to identify and study specific gene-environment interactions

that confer susceptibility. Such mechanistic insights can then be used to inform and focus epidemiological studies.

Clearly, research is urgently needed to better predict which combination of defective genes and environmental exposures pose the greatest risk for NDDs. The fact that environmental factors are modifiable risk factors, in contrast to currently irreversible genetic risks, suggests that identification of specific environmental risk factors may provide rational approaches for the primary prevention of NDDs, which provides a compelling reason to invest in this endeavour.



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Supporting healthy forests across America

Open Access Government highlights the role of forests within biodiversity and how the USDA supports agroforestry in America

Forests are said to play one of the most important roles in biodiversity. They cover 31% of the world's surface, with the US and Canada being 2 of the 5 countries with the biggest forest areas worldwide. As well as playing a role in the environment, forests also provide more than 10% of the GDP in many poorer countries and the forestry sector is estimated to provide formal employment for 10 million people. In order to protect our forests and reduce deforestation, which occurs in many countries, sustainable forest management is key.

To ensure the protection of forests and its wildlife, the Food and Agriculture Organization of the United Nations (FAO) works to improve knowledge on sustainable forest and wildlife management. It also supports the development of policies and practices to improve the capacity of forests, conserve biodiversity, as well as sustain wildlife populations.

According to the FAO report, '[State of the World's Forests 2016](#)', forests play key roles in water cycle soil conservation, carbon sequestration and habitat protection, as well as their sustainable management being crucial for sustainable agriculture and food security.

USDA and agroforestry

The US Department of Agriculture (USDA) also plays a role in developing healthy forests. Agroforestry is a process that combines both agriculture and forest technologies in order to create more integrated, diverse, productive, and sustainable land-use systems.

[The USDA Agroforestry Strategic Framework](#) aims to provide new direction on how USDA agencies, partners and landowners can together significantly expand agroforestry to balance agricultural production with natural resource conservation.

USDA states that the key concept in agroforestry is 'working trees – putting the right tree in the right place, for the right purpose'.

Through their strategic framework, the US agroforestry community is provided with an opportunity to positively influence the long-term health and sustainability of all lands for future generations.

Supporting forests using farming techniques

There are a number of farming techniques that utilise and support forests. These are intended to make the best use of available, land, especially in rural areas, and work alongside nature without clearing areas of forest or disturbing habitats or natural processes.

“Farming systems must adapt in order to both meet increasing demands and maintain the environment at a time when it is at risk.”

[Silvopasture](#) is the practice of grazing livestock in fields with trees. This provides the animals with shelter and shade and allows them to use the same area for producing wood. This lowers stress in animals and provides a dual income for farmers, as well as preserving natural habitats and reducing the risk of wildfires.

[Agrocropping](#) involves planting trees or shrubs in rows to provide alleys in which to plant crops for fruit, vegetables, herbs, and biofuels. Again, it allows for a dual use of land and is more environmentally friendly than normal farming practices. It also allows for a better use of nutrients within the same space, as the plants and trees selected can make the best use of the soil environment and complement each other's development.

[Forest farming](#) is a specialised practice that uses the protection of forest canopies to produce valuable



crops such as shitake mushrooms and other speciality ingredients. This also allows for additional income through timber production and provides a chance for more specific products like hazelnuts and maple syrup to be produced.

The USDA supports scientific research into agroforestry, with the intention of improving the cost-effectiveness and produce yield for farmers. They aim to educate farmers and allow for more opportunities for agroforestry, leading a global support for sustainable farming.

Agriculture can often pose a threat to biodiversity, with areas of land being cleared and repurposed, and natural food chains being disturbed. Agroforestry techniques provide a method of maintaining biodiversity, but the USDA has a number of directives for achieving this. In the face of climate change and ever-increasing demands for food, maintaining the natural environment is becoming a more difficult and essential task.

The USDA's mission statement seeks to improve the relationship between agriculture and the natural environment. Their suggestions for ensuring the protection of biodiversity include:

- Assessments to identify at-risk species and environments;
- Ensuring genetic diversity to increase resilience of wildlife;
- Identifying patterns of growth and decline, as well as changes in behaviour;
- Integrating climate protection into agriculture practice.

Farming systems must adapt in order to both meet increasing demands and maintain the environment at a time when it is at risk. The USDA is taking a systematic, ongoing approach to making environmental protection an essential part of farming. ■

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Climate change and its impact on beef cattle

Developing genomic tools for increased thermotolerance in beef cattle is imperative, says University of Florida's Associate Professor Raluca Mateescu

Climate change and beef cattle

Heat stress is the principal factor limiting production of animal protein and negatively affecting the health and welfare of cattle in subtropical and tropical regions. Detrimental effects on livestock productivity associated with heat stress are expected to intensify and expand into currently temperate zones upon the realisation of predicted climate change (Figure 1). The Intergovernmental Panel on Climate Change (IPCC), which includes more than 1,300 scientists from the United States and other countries, forecasts a temperature rise of 2.5 to 10 degrees Fahrenheit over the next century. Most animal-producing areas in the US are predicted to experience extreme summer conditions and by 2100, average temperatures in the US are projected to increase 2° to 6°C, depending on the emissions scenario and climate model applied. The number of days with maximum temperatures above 32°C (90°F) is expected to increase. The SE and SW areas of the US currently average 60 such days per year but is projected to experience at least 150 such days a year by the end of the century.

Importance of genomics for improved thermotolerance

Development of effective strategies to improve the ability to cope with heat stress is imperative to enhance the productivity of the US livestock industry and secure global food supplies. Although swine, poultry and dairy

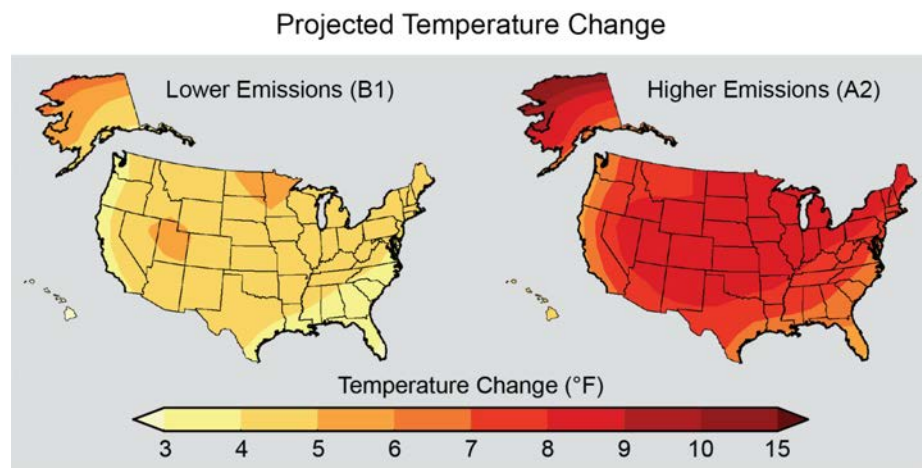


Figure 1: Projected Temperature Change. Warming is projected for all parts of the nation during this century. In the next few decades, this warming will be roughly 2°F to 4°F in most areas. By the end of the century, U.S. warming is projected to correspond closely to the level of global emissions: roughly 3°F to 5°F under lower emissions scenarios (B1) involving substantial reductions in emissions, and 5°F to 10°F for higher emissions scenarios (A2) that assume continued increases in emissions. (Figure source: NOAA NCDC / CICS-NC)

cattle are more severely affected by heat stress than beef cattle, their confinement and intensive production systems make climate control via housing design and management interventions feasible. Beef cattle, particularly those in the cow-calf segment, are typically reared in extensive systems with limited opportunities for controlling environmental stress (Figure 2). Genetic improvement is one of few feasible strategies for ensuring adequate and sustainable production of beef protein in an increasingly hot world. Substantial differences in thermal tolerance exist among breeds and among animals within breeds indicative of opportunities for selective improvement. For example, *Bos indicus* cattle exhibit increased resistance to many environmental stressors relative to *Bos taurus*,

but tend to have slower growth, lower fertility and meat quality as they have not been as intensively selected for these traits as specialised *Bos taurus* breeds. Use of genomic tools to produce an animal with superior ability for both thermal adaptation and food production represents an energy-efficient sustainable approach to meet the challenge of global climate change.

What is thermoregulation?

Thermoregulation is a process in which environmental information provokes an appropriate response (e.g., vasoconstriction, panting), to maintain body temperature within the narrow range necessary for optimal cellular and molecular function. This is accomplished by jointly regulating heat production and heat loss. Beef cattle regulate internal heat production (by



Figure 2: Bos Indicus cattle are naturally adapted to survive in tropical and subtropical environments

modulating basal metabolic rate through thyroid hormone actions and changing feed intake, growth, lactation, and physical activity) and heat exchange with the environment (by increasing blood flow to the skin, and increasing evaporative heat loss through sweating, panting and behavioural wetting of the skin). Hyperthermia results when these adjustments are not able to mitigate the environmental heat stress and body temperature increases. Improvements in production, such as increased growth rate, lead to increased metabolic heat production and exacerbate the problem of thermoregulation. Thus, for example, there is a negative genetic correlation between milk yield and ability to regulate body temperature during heat stress in dairy cattle. Unless accompanied by changes that increase heat loss capacity, improvements in production make animals more susceptible to hyperthermia during heat stress.

Genomics for climate smart beef

The strategy we are undertaking is to reveal the genetic architecture of traits defining thermal tolerance using Bos

indicus influenced cattle, in particular, Brangus (Brahman x Angus). In comparison to straight Bos taurus populations, we expect that the major genetic variants controlling thermal tolerance will be segregating in these indicine-influenced populations due to the length of time since divergence of the two subspecies, natural adaptation to different environments, and exposure to an artificial selection of different intensities and with different objectives. Our goal is to discover genetic variants responsible for thermal tolerance and use this knowledge to develop genomic tools to improve thermal tolerance in cattle populations at risk of exposure to heat stress.

Our research will use a system biology approach by integrating genomics and phenomics with additional -omics data to understand the genetic architecture of thermal tolerance. Frequent body temperature measurements, skin temperature, and perspiration rate in free ranging cattle will be recorded during heat stress on 2,000 Brangus heifers genotyped with the 250K functional SNP chip. Phenomics for thermal tolerance and genomic

data will be integrated to identify chromosomal regions associated with regulation of body temperature. We will use this information to develop tools to be used in selection and management programs designed to mitigate the effect of heat stress in indicine-influenced beef cattle populations that predominate in hot and humid regions of the US and globally.

In depth knowledge of the genomic variants with major effect on thermal regulation and the maturation of technologies for gene, editing means that thermotolerance genes can be rapidly introduced into thermally-sensitive breeds such as Angus, Simmental, and Holstein to allow producers to exploit genetic lines of cattle selected for high productivity with minimal disruption by heat stress. Development of 'the cow of the future' with high productivity and resistant to heat stress will be realised through the use of genomic selection within indicine-influenced breeds and through the application of gene editing technologies that allow genetic variants conferring thermal tolerance to be rapidly incorporated into non-adapted breeds.

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Some essentials on coexisting with carnivores

Coexisting with carnivores can be a challenge, but their value makes it worthwhile

The well-being of many human communities depends on healthy forests and grasslands. Those ecosystems can be degraded by over-browsing and over-grazing by large herbivores – moose, deer, elk, gazelles and so forth. That overconsumption is far less likely to occur when large herbivores are limited by healthy populations of large carnivore – wolves, lions, lynx, wolverine, bears, etc. Moreover, ecosystems with healthy populations of large carnivores tend to have greater levels of overall biodiversity. In a nutshell, and at risk of glossing over details, the conservation community has concluded that large carnivores have great ecological value.

Nevertheless, human communities often find it difficult to live near populations of large carnivores. Difficulties arise in three ways. First, carnivores kill domestic livestock, which provide for the well-being of some humans. Carnivores do not kill for malice; they do so because their well-being depends on it. Moreover, carnivores would naturally prey on wild animals. In many cases, however, the wild prey have been displaced by domestic livestock.

Second, carnivores kill wild prey that are also hunted by humans for subsistence or recreation. In this way, large carnivores are treated as competition to be eliminated.

Third, some species of large carnivores, on some occasions, threaten



and take human lives. Important examples include human-eating lions in portions of Africa and human-eating tigers in portions of south Asia.

While these three elements of conflict are real, they are also frequently and grossly exaggerated. In the United States, for example, the impacts of wolves on livestock and hunting are very small and wolves do not pose a threat to human safety¹. Yet, these concerns are important fuel for wolf persecution.

Under threat

Genuine and perceived threats lead to humans killing carnivores at high rates through illegal poaching and legal culling and hunting. The result of all this killing is that two-thirds of the world's

carnivore species are threatened with extinction and most places do not have their native complement of carnivores. The end point of treating this conflict – as humanity has thus far – is irreversible extinction and gross mistreatment of carnivores that manage to persist. An important element of this conflict concerns the received and oft-repeated motivation offered for why carnivores should be treated better: because they are ultimately of value to humans. The genuine wellbeing of humans is an important reason to conserve, but it is not the only one and alone it is inadequate.

European colonists and their descendants drove various large carnivores to extinction over a substantial portion of eastern North America. Britain

drove its large carnivores – wolves, lynx and brown bears – to extinction centuries ago. It is difficult to mount a case that the wellbeing of those humans is worse as a result of those extinctions. When an object (think, carnivores) is valued only for its utility, its utility may go unrecognised, be outweighed by costs of maintaining it, or replaced by a substitute. This is not a denial of carnivores' utility, but acknowledgement of the risk in valuing something only for its utility. As such, nature's utility is an (important, but) insufficient motivation for conservation.

“Genuine and perceived threats lead to humans killing carnivores at high rates through illegal poaching and legal culling and hunting. The result of all this killing is that two-thirds of the world's carnivore species are threatened with extinction and most places do not have their native compliment of carnivores.”

Conserving carnivores

What if, carnivores are valuable, not only for advancing human wellbeing, but also because they have a value in their own right? What if, we have an obligation to treat carnivores fairly and with at least some concern for their wellbeing? The response to those questions begins with the supposition that humans possess this kind of value and are entitled to this kind of treatment because we have interests (e.g., to avoid pain and to flourish). It follows that any entity with such interests would also possess this kind of value. Because all vertebrate organisms possess those interests, they also possess this kind of value and deserve this kind of treatment. The force and universality of this reasoning is indicated by the principle of

ethical consistency, i.e., treat others as you would consent to be treated in the same position. Most human cultures are undergird by some variant of this principle (e.g., golden rule). This intrinsic value of at least some non-human portions of nature is widely acknowledged – reflected by sociological evidence and many instances of laws and policies. Ethicists encapsulate these ideas by saying that carnivores (and many other forms of life) possess intrinsic value².

Future success in carnivore conservation will depend, in part, on better understanding ideas that will foster effective and fair mitigation and adjudication of conflict, especially:

- The extent to which conservation can be achieved through protected areas and land-sparing, opposed to land sharing³;
- Mechanisms of socioeconomic behavior that adversely impact carnivores. Some elements may be underappreciated (e.g., wealth inequality,⁴) and other elements may be favorable to conservation (e.g., tendency to increasingly embrace nature's intrinsic value with increasing economic development,⁵);
- How to subsidise coexistence by compensating those adversely affected by living with carnivores. The challenge is tailoring compensation in ways that are fair and effective, yet do not foster, e.g., perverse incentives, additionality, or leakage⁶;
- How to best juxtapose the values of conservation and social justice in a manner that genuinely honors the intrinsic value of carnivores without being misanthropic⁷.

Conservation is no longer limited by ecological knowledge about carnivores' ecological value or needs. Increasingly, the limiting factor is effective application of knowledge rising from the synthesis of social sciences, social justice and conservation.

1 Vucetich (2016), Oversight Hearing, United States House Of Representatives. <https://www.gpo.gov/fdsys/pkg/CHRG-114hhrg-21616/pdf/CHRG-114hhrg21616.pdf>

2 Vucetich et al. (2015), *Conserv Biol*, <https://doi.org/10.1111/cobi.12464>

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Good marine health remains a challenge due to climate change

Climate change and marine health are intrinsically linked. Open Access Government's Ciara Ruane explains how the National Science Foundation supports both

Marine health is an essential part of the war against climate change. The US National Science Foundation (NSF) highlight it as a key issue, of both economic and environmental significance. The NSF's Division of Ocean Sciences (OCE) promotes collaboration between scientific and educational fields to tackle these challenges head on. Through research support and funding, the OCE provides knowledge which is critical to addressing some of the most pressing environmental challenges involving earth processes. Ocean research looks to the future, with a focus on expanding weather forecasting abilities to predict weather years in advance. Oceans are a key factor in innovations such as these.

“The greater metabolic strain required in these environments creates a greater need for oxygen, which is lacking. The study revealed that these changes cause animals to migrate away from the equator.”

The NSF hopes that the need for more accurate weather predictions in the face of climate change will mean more funding for ocean research. They also believe that physical oceanographers have made an ‘enthusiastic’ start on the issue, giving hope for big advancements in the field over the next decade. However, they also name global climate prediction ‘one of the most difficult’ problems scientists in the field of ocean study have faced.

The average lifespan only sees a few incarnations of the oceanic climate system, meaning it is extremely difficult to gather extensive data on the subject. The NSF is currently running a funding programme for the Center for Ocean-Land-Atmosphere studies. This awards grant funding to “1) basic research on pre-

dictability on intraseasonal, seasonal, interannual, and decadal timescales; 2) evaluation of the predictability, skill, and fidelity of US national climate models; and 3) contributions to the development of next generation seamless prediction systems.”

The grant aims to work towards developing more accurate models of climate prediction and boost knowledge of Earth's oceans through community integration and education as well as the funding of scientific research.

Mapping

Another goal for the NSF is ocean observation and mapping. Innovations like the TOPEX/POSEIDON satellite mission allow for a level of ocean observation accuracy within the centimetre. Ocean floor mapping is essential for scientists to understand much of how the world works. Continental shift, ocean currents and ‘ecological niches’ can all be explored and discovered through the technique. However, advancements still must be made. The current technology utilises sound waves to create images of what lies under the sea.

Sound wave technology is mainly used by ships to create localised maps, and allows for enormous detail compared to previous mapping techniques. In recent years new submarine formations, volcanoes, hot springs, and trenches have been uncovered. In 2014 the NSF published an article about new discoveries made with satellite data. Authors of that study said that 80% of the ocean floor at the time was still unmapped. The most recent and advanced image of the ocean's geography, made with data from a NASA satellite, can capture ‘any feature larger than 5km’. This map was made by detecting gravitational anomalies. This is a fairly recent advancement from sonar technology, and represents a potential new path for geographical surveying.



“Ocean floor mapping – is essential to scientists to understand much of how the world works. Continental shift, ocean currents and ‘ecological niches’ can all be explored and discovered through technique. However, advancements still must be made. The current technology utilises sound waves to create images of what lies under the wave.”

Warming waters

Scientists fear that oceans becoming warmer and less oxygen-rich in the face of climate change presents a challenge for marine wildlife. In 2015 the NSF outlined a study on the effect these changes would have on Atlantic rock crabs. Irwin Forseth, of the National Science Foundation’s Division of Integrative Organismal Systems, said of the study: “Understanding connections such as this is essential to allow us to predict the effects of environmental changes on the distribution and diversity of marine life.”

The greater metabolic strain required in these environments creates a greater need for oxygen, which is lacking. The study revealed that these changes cause animals to migrate away from the equator. Cod numbers are also threatened by these changes, with their population already in decline. This obviously has indications for feeding earth’s population, but would also create disturbances in the marine ecosystems and food chains. Further monitoring of such changes will be essential to adapt to the effects of a changing climate and prevent the worst of it. ■

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Supporting Alaska Native students through education

Dr. Herb Schroeder from the Alaska Native Science & Engineering Programme (ANSEP) outlines why it's integral to develop the skills of Alaska Native students

Alaska is a huge place with a very limited road infrastructure. Alaskans rely upon air travel to get to the bulk of the communities in the state. The people living outside of the metropolitan hubs of Anchorage, Fairbanks, and Juneau rely heavily upon fish and game to subsist. These communities are not connected to the power grid. Alaska Native people have lived here for 10,000 years.

Alaska rural communities face many unique challenges, including challenges to development and economic self-sufficiency; geography and climate; isolation; unemployment; high cost and low standards of living; and infrastructure issues including lack of clean water and sewers. There are 737,000 people in Alaska and 143,000 Alaska Native people. About 22.6% of the K-12 students in the state are Alaska Native, and most rural schools have fewer than 100 K-12 students. Many students never receive preschool education, due the schools being geographically isolated and teachers are difficult to find and retain. This is particularly so for math and science teachers. As a result, the coursework required to be prepared for STEM BS degrees is often not available in the schools. Rural Alaskan villages have some of the worst literacy rates in the nation. Also, Alaska Native students are less likely to pass standard tests than any other demographic, and are more likely to drop out of school than any other demographic.



ANSEP engineering students work through a math problem during a study group in the learning center that was built to support ANSEP students on the campus at the University of Alaska Anchorage

The 2014 ACT College Readiness Benchmark scores show that 5% of Alaska Natives meet all four benchmarks. The percentage meeting the individual benchmarks are:

- Science 7%
- Math 15%
- English 21%
- Reading 15%

This presents a formidable challenge when moving students through the university and into graduate school and the professions. Yet, the Urban Institute has shown that ANSEP students at every level are successful at rates higher than national averages for all students.

The Alaska Native Science & Engineering Programme (ANSEP)

Started in 1995, the Alaska Native Science & Engineering Programme (ANSEP) at the University of Alaska Anchorage, is a community that includes more than 100 industry partners, philanthropic organisations, as well as federal and state agencies. These organisations provide financial support, internships, research projects and advocacy. There are more than 2,000 ANSEP students from sixth grade through the PhD.

The ANSEP Components Middle School Academy

Middle School Academy is a two-week, residential, science and engineering experience. Academy students build a

top end PC from scratch and earn the right to keep it by successfully completing algebra 1 prior to eighth grade graduation, complete hands on science and engineering projects in teams of 3, live in the university residence halls, and experience what it is like to be a scientist or engineer. Each Academy has 54 students, half boys and half girls. The Urban Institute has found that 77% of the Academy students meet the goal of completing algebra 1 before eighth grade graduation. The national average for all students is 26%.

STEM Career Explorations

STEM Career Explorations keeps middle school students excited and engaged each subsequent year they are in middle school. Career Explorations brings students who have successfully completed the Academy back to campus for an intense five-day hands-on project based exploration exercise. Eligible students must be making progress toward finishing algebra 1 prior to eighth grade graduation.

Acceleration Academy

Acceleration Academy is for high school students. Students benefit from having direct access to a college environment, university faculty, and an encouraging peer group. Students are engaged with hands-on engineering and science projects, whilst enrolling in college-level classes, taught by UAA faculty. The Urban Institute has found that 95% of students advance at least 1 full level in math or science during each session.

Acceleration High School

Acceleration High School is a year round full-time high school. We kicked it off in August 2016. It is modelled after the summertime ANSEP Acceleration Academy, which we started in 2010. In the school, university faculty are instructors and students who earn

dual (high school and university) credit. This decreases the time to high school graduation while allowing students to earn 30-50 university credits towards an engineering or computer science degree and solves the problem of students arriving at the university underprepared. It also saves the state K12 funding, increases retention, and saves students and their families at least a year of tuition and living expenses. Instruction in the school is collaborative, experiential, inquiry and research based, culturally appropriate, and involves peer and professional mentoring, skill building seminars, academic advising, intensive academic enrichment, and career awareness.

Summer Bridge

During the Summer Bridge, new high school graduates live on the University of Alaska Anchorage campus, work full-time in paid professional internships doing real work in the oil industry, with state and federal agencies, or university and agency laboratories, and complete 160 hours of calculus or science instruction for university credit. Some students work out in the field while others gain experience working in a corporate setting, but all students broaden their knowledge of career opportunities as they focus on solving real-world problems in engineering and science. It is designed to be a fast paced, challenging experience with the opportunity to earn scholarship support and develop professional networks for future internships and careers.

University Success

The University Success component fosters an engaged learning community focused on academic success and professional development. During University Success, students are teamed in an academic community and, supported by peers and professionals, work together for success.

University success students earn scholarships, work in organised peer study groups, benefit from skill building seminars, gather in the ANSEP Building, benefit from academic advising, internships, research experiences, peer and professional mentoring, conference participation, career awareness, GRE test preparation, graduate school admissions support and undergraduate research. The Urban Institute has found that 75% of ANSEP University students since 2010 have graduated or are still enrolled.

Alaska Grown PhD

The Alaska Grown PhD provides access to tenure track faculty positions in engineering and science on our campus. The component has produced 2 PhDs so far and both are on the UAA College of Engineering faculty. Dr. Matt Calhoun is the only Alaska Native PhD in the world in civil engineering and Dr. Michele Yatchmeneff is the only Alaska Native PhD in the world in Engineering Education. Both earned their undergraduate degrees as ANSEP students.



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Polar vortices and their interactions

What are polar vortices, and how do they influence the rest of the atmosphere and climate system? Johns Hopkins University's Professor Waugh explains

Polar vortices are planetary-scale systems comprised of rapid west-east flow that circumnavigates the pole in middle or high latitudes. These vortices influence not only the Polar Regions where they exist, but their influence also extends into the tropics and down to the surface, as well as into the oceans. As a result, polar vortices play an important, but often underappreciated, role in Earth's climate and weather.

In each hemisphere there are 2 distinct polar vortices in Earth's atmosphere: one in the troposphere (lowest 10-15km of the atmosphere) and one in the stratosphere (10-50km). These 2 polar vortices differ not only in their vertical extent but also in their latitudinal scale and seasonality: The tropospheric polar vortex is larger than in the stratosphere and it exists all year, whereas the stratospheric polar vortex exists only from fall to spring. The existence of 2 distinct polar vortices with different characteristics, and impacts on the rest of the atmosphere, has led to some confusion in the press and social media.

Stratospheric vortices

The most pronounced influence of stratospheric vortices in Earth's climate system is their role in stratospheric ozone depletion. Very low temperatures occur within these vortices, and this is a necessary requirement for the chemical processing that leads to the destruction of ozone by chlorine and

bromine species. Furthermore, vortex air is largely isolated from surrounding air, containing ozone depletion within Polar Regions. The formation of the Antarctic ozone hole but not an equivalent Arctic ozone hole occurs because the Antarctic vortex is less disturbed and colder than its Arctic counterpart.

"Polar vortices are not exclusively a feature of Earth's atmosphere, and there are polar vortices in the atmospheres of Mars, Venus, Saturn, and Saturn's moon Titan. Many similarities exist among these polar vortices, including strong winds circumnavigating a cold winter pole, and the occurrence of unique chemical processes within the vortices (ozone depletion on Earth, and formation of CO₂ clouds on Mars and HCN clouds on Titan)."

The influence of stratospheric polar vortex is not confined to the stratosphere. The strengthening of the Antarctic polar vortex over the last few decades due to ozone depletion, has contributed to a southward shift in the Southern hemisphere tropospheric circulation as well as changes in the Southern Oceans. Stratospheric vortex – surface connections also occur in the Northern hemisphere, with a disturbed, weak Arctic stratospheric vortex linked with an increased likelihood of the movement of cold tropospheric air from Arctic into middle latitudes (so called cold-air outbreaks).

The connection with cold-air outbreaks is more direct for the tropospheric polar vortex. During cold-air outbreaks there are generally planetary-scale distortions of edge of the tropospheric vortex, where part of the vortex is displaced further equatorward than normal, while at other longitudes the edge is further poleward. Anomalously cold surface air occurs in regions of equatorward displacement of the vortex edge. The cold-air outbreak over the United States in January 2014 that gained a lot of media attention is a classic example of this tropospheric vortex – cold surface air connection.

While much progress has been made in recent years on polar vortex – surface connections, there remain many areas where a greater understanding is required, for both climate and extreme weather. My research group and collaborators are currently exploring some of these issues, including the relative contribution of each vortex on surface extreme weak events, and the impact of the Antarctic stratospheric vortex on the ocean circulation.

Polar vortices are not exclusively a feature of Earth's atmosphere, and there are polar vortices in the atmospheres of Mars, Venus, Saturn, and Saturn's moon Titan. Many similarities exist among these polar vortices, including strong winds circumnavigating a cold winter pole, and the occurrence of unique chemical processes within the vortices (ozone depletion on Earth, and



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formation of CO₂ clouds on Mars and HCN clouds on Titan). There are, however some very distinctive differences. For example, Mars polar vortices have an annular structure, Saturn's Northern polar vortex has a persistent hexagonal shape, and Venus' Southern vortex experiences dramatic changes in its internal structure and shape.

“The connection with cold-air outbreaks is more direct for the tropospheric polar vortex. During cold-air outbreaks there are generally planetary-scale distortions of edge of the tropospheric vortex, where part of the vortex is displaced further equatorward than normal, while at other longitudes the edge is further poleward.”

Martian polar vortices

My group and collaborators have been examining the structure of Martian

polar vortices. The persistence of Mars' annular polar vortices is surprising as classical fluid dynamical theory would suggest it would be unstable. It turns out that the existence and persistence of the Martian polar vortices is related to another distinctive feature of Mars' atmosphere: the condensation of the predominant atmospheric gas species (CO₂) that occurs inside the polar vortices. The latent heat release associated with this condensation modified the stratification and leads to the formation of the annular structure, and also suppresses the growth of instabilities. An open question is whether this also facilitates mixing of dust and trace gases across the vortex edge. This, and other transport issues, is a current avenue of research. As is the structure, dynamics and chemical processes of other polar vortices. The range of planetary vortices across the

Solar System allows us to determine the commonalities of polar vortices in general, and to improve scientific understanding of the role they play in regulating a planet's atmospheric compositions and climate.



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Innovation is necessary to create clean, efficient energy

Open Access Government highlights how the US Department of Energy is streamlining energy use to improve economic efficiency and provide clean energy

The US Department of Energy (DOE) is looking to scientific innovation to streamline energy use, improve economic efficiency, and provide sources of clean energy. Currently, around 65% of electricity in the US is sourced from fossil fuels, around 20% is from nuclear energy, and 15% is from renewable energy (biofuels, wind power, solar).

Fusion energy

A particularly ambitious potential energy source is fusion power. Essentially recreating the energy conversion process of a star, fusion energy involves the study of plasmas, hot gases that respond to electricity and magnetic fields which form such things as stars, auroras, fire, and lightning. If successful, fusion energy would provide an eternally renewable and CO₂ neutral form of power. It also would produce no radioactive waste. A machine called a tokomak is currently being used in a DOE lab to create and experiment on fusion processes.

Currently, there are still several challenges standing in the face of achieving sustainable fusion energy. The DOE is leading an initiative to create a supercomputer 50 times faster than current technology to create simulations that will move fusion technology along. Capable of a billion calculations a second, such a computer would provide accurate predictions of fusion reactions, which would accelerate the technology and help the DOE achieve its goal of making fusion energy commercially viable.

NETL

The National Energy Technology Laboratory (NETL), an offshoot of the DOE, conducts internal and collaborative research to accelerate the DOE's goal of improving fuel efficiency in the US. The NETL's laboratories in West

Virginia are using a Fischer-tropsch reactor to develop a method to remove sulphur from fossil fuels. This aims to make them burn cleaner, as well as extracting other useful chemicals from natural gas. In their Pittsburgh, PA lab they are conducting experiments with the aim of turning fuels like biomass and coal into gas, making it easier to contain their CO₂ emissions. Innovations such as these work on a basis of improving fuel sources that are currently in use. Research into alternative renewable fuel also runs alongside this.

Biofuels

Biofuels have become a subject of debate in recent years. Long touted as a clean, renewable alternative to fossil fuels, new research suggests they may do just as much harm. The UN released a report in 2014 warning that growing plants for biofuels drives up food prices and creates just as much harm for the environment. Biofuel production relies on growing crops such as rapeseed, which means either repurposing agricultural land or clearing forests to free up more space. Some environmentalists also believe that liquid biofuels release just as much CO₂ as traditional fossil fuels, if not more.

The DOE is working on making biofuel production cleaner and more cost-effective. The Abengoa Bioenergy project in Hugoton, Kansas, is a cellulose ethanol plant financed by the DOE that converts non-edible biomass into fuel. Rather than taking up agricultural land, the plant uses corn stalks, leaves, and other non-edible plant products leftover from the farming process. Another DOE-backed project uses algae for biofuels. It does not compete for farm land in its production, and creates more usable fuel than other products such as soybeans. It can be grown in saltwater and wastewater, meaning less water wastage. It can also produce other



useful products such as fertiliser. However, the technology is still in its infancy, and requires further research to become more cost-effective and readily available.

Renewables

The DOE's [SunShot initiative](#) aims to cut the cost of solar power in half by 2030, making it an affordable go-to source of power. By increasing efficiency, improving energy storage, and speeding up the process, they intend to reduce costs from 7¢ per kilowatt hour to 3¢ by this point. Other DOE investments cover wind, water, and geothermal power. In 2008 the DOE published a report entitled '[20% Wind Energy by 2030](#)', examining the possibility of producing a fifth of the US's energy from wind. It concluded that achieving this goal would require an increase in turbine production from 2000 per year in 2006, to 7000 per year in 2017. The number of turbine installations has increased dramatically since the beginning of the year, with the [American Wind Energy Association](#) releasing a report in May stating that a new turbine was installed every 2.5 hours.

The DOE's mission involves a two-pronged approach of improving existing sources of energy in terms of cleanliness and efficiency, and investing in green and renewable sources at the same time. The US has a deeply ingrained infrastructure revolving around fuels like coal, oil, and nuclear energy, meaning a switch to alternative power would require an adaptation on many levels, and is not just a question of placing all investment in green energy. More research will be needed in fields like fusion energy and algae biofuels for them to compete with existing energy infrastructure. ■

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Exploring lower cost pathways to economical fusion power

The cost of fusion energy development is a significant reason why progress remains challenging. Scott C. Hsu of the Los Alamos National Laboratory explains

When I entered graduate school in 1993 to study plasma physics and fusion, the United States already had designs to build a “burning-plasma” fusion experiment in which the power produced by fusion would, for a short duration, exceed the heating power required to sustain those reactions¹, i.e., “scientific breakeven.” Had we proceeded then to build such an experiment, we might have achieved that milestone a decade ago. The experiment was never built, and, instead, the multi-national collaboration ITER² is now aiming to fulfill this mission. ITER’s final cost is projected to exceed US\$20bn³, and it will take nearly another 20 years from today before ITER might demonstrate scientific breakeven. Fusion science and technology have advanced significantly since 1993, but we have frustratingly regressed with respect to the timeline for realising commercial fusion power. Why?

The two biggest, interrelated reasons that progress toward fusion power has slowed to a crawl, in this author’s opinion, are (a) the significant cost (>US\$10bn) of constructing a burning-plasma experiment based on the most scientifically mature approach (the tokamak), and (b) the absence of consensus that fusion energy is urgently needed. Such consensus, if it can be established, would increase the available public funding and therefore the rate of progress. At the

present rate of progress, commercial fusion power will not be realised in time to impact midcentury carbon-emission targets. All projected energy solutions (e.g., renewables with storage, fossil fuels with carbon sequestration, and advanced nuclear fission) have daunting challenges of their own to overcome in order to achieve the scales needed to meet midcentury energy demands. More timely development of fusion energy would greatly increase our chances of achieving an adequate carbon-free energy mix. But how do we increase the rate of progress toward realising economical fusion power, given the socio-political realities?

Lowering costs

There are many proposed pathways to fusion energy that are potentially “faster and cheaper” compared to the development path based on ITER. In the remainder of this and a series of subsequent articles, we draw from the story of our own fusion research to explore and advance a lower-cost development pathway toward economical fusion power, benefitting from and complementing mainstream fusion research that is centred around ITER. We assert that lowering fusion-development costs is essential to



Figure 1. Photo of the outer (top) and inner (bottom) electrodes of a (disassembled) coaxial plasma gun used to launch supersonic plasma jets in our fusion research. Photo courtesy of HyperV Technologies Corp.

accelerate fusion development, such that fusion might penetrate power-generation markets by 2050. Our journey over the past decade benefitted from desirable aspects of a public-private partnership to develop fusion, but our path occurred against great odds, whereas such paths should be enabled systematically throughout the worldwide fusion-development enterprise to improve its chances of timely success.

Our research is focused on developing a reactor-friendly embodiment of magneto-inertial fusion (MIF), aka magnetised target fusion (MTF). MIF is a class of approaches involving the compression of a magnetised target plasma (consisting of the fusion fuel)

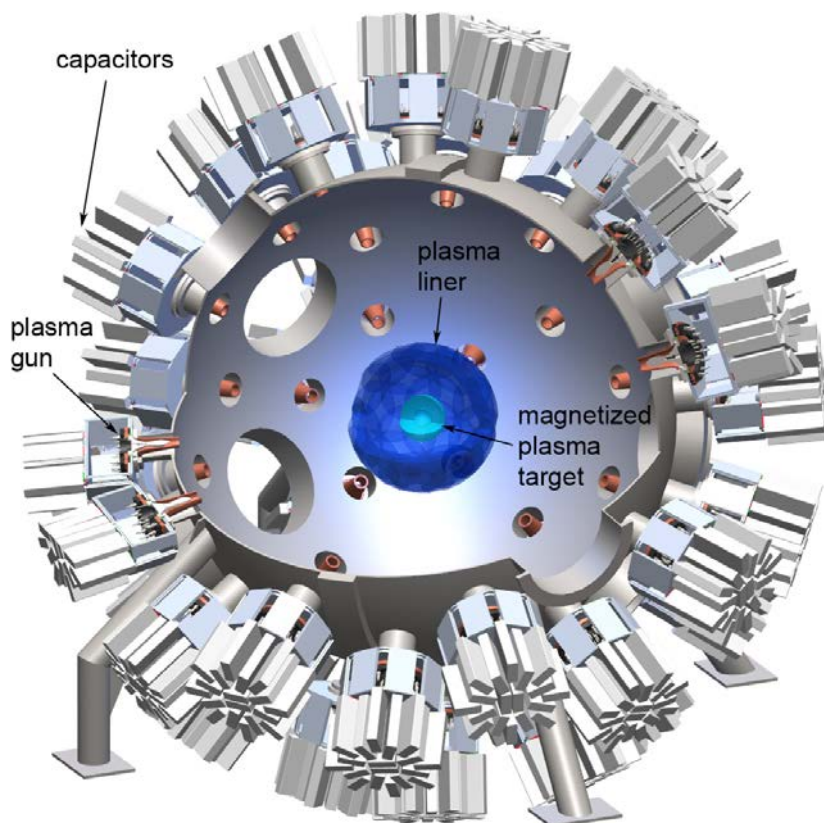


Figure 2. The objective of our research: to form a spherically imploding plasma liner (by merging 60 plasma jets) that will be used to compress a magnetized target plasma to fusion conditions. The cutaway spherical vacuum chamber is 2.7 m in diameter. Figure courtesy of HyperV Technologies Corp.

to fusion conditions by an imploding pusher, called a “liner.” For example, the Canadian company General Fusion is developing MTF via acoustically driven liquid lead-lithium as their liner. MIF is inherently lower cost than other fusion approaches because MIF aims to achieve a compressed fuel density that optimises the combination of plasma heating power and stored energy required to achieve fusion conditions⁴, thereby minimising the capital cost of the required facility. On the other hand, for historical and myriad other reasons, the mainstream, most scientifically mature approaches of magnetic-confinement fusion (MCF, such as ITER) and inertial-confinement fusion (ICF) operate at the lowest and highest extremes of fuel density, respectively. As a result, due to basic laws of plasma physics, MCF requires very large size and stored energy, and ICF requires very high power to compress the fuel, which both drive costs

into the multi-billion (\$US) range for breakeven-scale facilities. In contrast, a breakeven-class MIF facility is expected to cost as little as a few hundred million dollars (\$US).

Our project, the Plasma Liner Experiment–ALPHA (PLX- α)⁵, is one of nine projects supported by the ALPHA Program⁶ of the Advanced Research Projects Agency–Energy (ARPA-E) of the U.S. Department of Energy (DOE). We use innovative, low-cost coaxial plasma guns (Fig. 1), developed and built by partner HyperV Technologies Corp.⁷, to launch a spherically converging array of supersonic plasma jets toward the middle of a large, spherical vacuum chamber (Fig. 2). A key near-term goal of PLX- α is to merge up to 60 plasma jets to form a spherically imploding plasma liner, as a low-cost, high-shot-rate driver for compressing magnetised target plasmas to fusion conditions. This approach is

known as plasma-jet-driven MIF (or PJMIF)⁸. A new startup company HyperJet Fusion Corporation (which recently received seed funding from Strong Atomics, LLC, a new fusion venture fund) aims to develop PJMIF under continued public and private sponsorship.

In an ensuing article, we will describe the key elements that led to joint public/private sponsorship of this research, in hopes of motivating public policymakers and private-sector investors to make such sponsorships more commonplace throughout the fusion-development enterprise.

¹ For example, Burning Plasma Experiment Special, Fusion Technology 21, 1045-1308 (1992); http://fire.pppl.gov/fusion_library.htm (accessed July 9, 2017)

² www.iter.org

³ http://www.firefusionpower.org/EU_US_ITER_Cost%20Estimate-s_2017.pdf (accessed July 9, 2017)

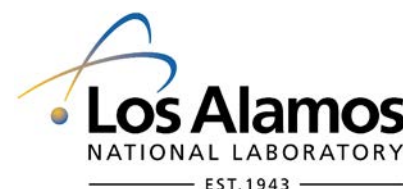
⁴ I. R. Lindemuth and R. E. Siemon, Amer. J. Phys. 77, 407 (2009)

⁵ <https://arpa-e.energy.gov/?q=slick-sheet-project/plasma-liners-fusion> (accessed July 9, 2017)

⁶ <https://arpa-e.energy.gov/?q=arpa-e-programs/alpha> (accessed July 9, 2017)

⁷ www.hyperv.com

⁸ Y. C. F. Thio et al., “Magnetized Target Fusion in a Spheroidal Geometry with Standoff Drivers,” in Current Trends in International Fusion Research – Proc. 2nd International Symp. (NRC Canada, Ottawa, 1999), p. 113; S. C. Hsu et al., IEEE Trans. Plasma Sci. 40, 1287 (2012).



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Space technology: how space benefits life on earth

M F Warrender highlights how space technology plays an integral role in society and how NASA invests in technology development

The National Aeronautics and Space Administration (NASA), was established in 1958 by President Dwight D. Eisenhower with the vision: “we reach for new heights and reveal the unknown for the benefit of humankind.” Since then, thousands of people have been working for NASA around the world to try and achieve this.

NASA addresses a number of key questions. What’s out there in space? How do we get there? What will we find? What can we learn from space that will make life better here on Earth? Throughout history, NASA has conducted or funded research that has led to numerous improvements to life here on earth, as well as also broadened our knowledge of space.

NASA conducts its work within 4 principal organisations, called mission directorates:

- Aeronautics;
- Human exploration and operations;
- Science;
- Space technology.

The latter of these mission directorates, space technology, is responsible for rapidly developing, innovating, demonstrating, and infusing revolutionary and high-payoff technologies that enable NASA’s future missions, while also providing economic benefit to the nation. NASA stands by its belief that technology drives exploration. NASA’s pioneering leadership in space is aided by sustained investments in technology, which advance the agency’s space exploration, science and aeronautics capabilities. The federal agency seeks to

improve our ability to access and travel through space; land more mass in more locations throughout the solar system; live and work in deep space and on planetary bodies; build next generation air vehicles, and transform the ability to observe the universe and answer profound questions in earth and space sciences. NASA also states that its technology development supports the nation’s innovation economy by creating solutions that generate tangible benefits for life on earth. NASA is without a doubt, investing in the future of innovation and the importance of research.

Space technology and innovation

Naturally, it would be easy to assume that the many science and innovation projects generated by NASA could often overlook the impacts on other sectors, such as health and the environment. Major programmes often have large environmental impacts, with science frequently and unintentionally overlooking the importance of the preservation of the climate. However, for many years, NASA has prided itself on its attention to environmental impacts, striving to lessen the use of ozone-depleting substances and the environmental consequences of research and innovation of space technology. This has been explicitly highlighted within a statement made by former NASA administrator Dan Goldin in 1994, in which he states: “NASA must be a leader in reducing the use of ozone-depleting substances and continue to identify programme and process revisions to reduce any adverse environmental impacts.”

Since then, this notion has been maintained and reinforced through recent programmes, securing NASA’s word on its environmental consciousness. The use of solar panels to power satellites has been a constant focal point of improvement, with NASA aiming to



Image: © NASA

The Earth Observatory's mission is to share with the public the images, stories, and discoveries about climate and the environment that emerge from NASA research, including its satellite missions, in-the-field research, and climate models.

develop traditional solar panels to make them more cost efficient and less bulky, ensuring that solar array technology can be at its best.

Supercomputers

Another example of NASA's environmental excellence is this year's new modular supercomputing facility – saving energy and water. Many facilities require significant amounts of water on a day to day basis and the task of powering these facilities consumes huge amounts of energy and water, for example, heating up and cooling down a high-end computing facility. A new system has recently been developed at Ames Research Centre in Silicon Valley, named Electra, which is expected to save about 1,300,000 gallons of water and a million kilowatt-hours of energy each year, equal to the annual energy usage of about 90 households. On top of this it will also save NASA about \$35 million dollars – about half the cost of building another big facility. Despite what might be assumed, the reduced use of water and energy resources does not lessen the system's capability. "The Electra system will provide users an additional 280 million hours of computing

time per year", according to Bill Thigpen, Chief of the Advanced Computing Branch at Ames' NASA Advanced Supercomputing Facility. It already ranks 39th in the US on the TOP500 list of the most powerful computer systems.

This is just one of many recent developments by NASA to help with conservation, and it just goes to show that space technology and science really can benefit other areas of society. NASA has been true to its word regarding its efforts with the environment, and as stated by Goldin, "Environmental excellence is a way of life and must be ingrained as part of our culture. Whether it is designing and fabricating robotic spacecraft, launching the shuttle, or conducting basic research, we must seek solutions which are environmentally benign."

M F Warrender

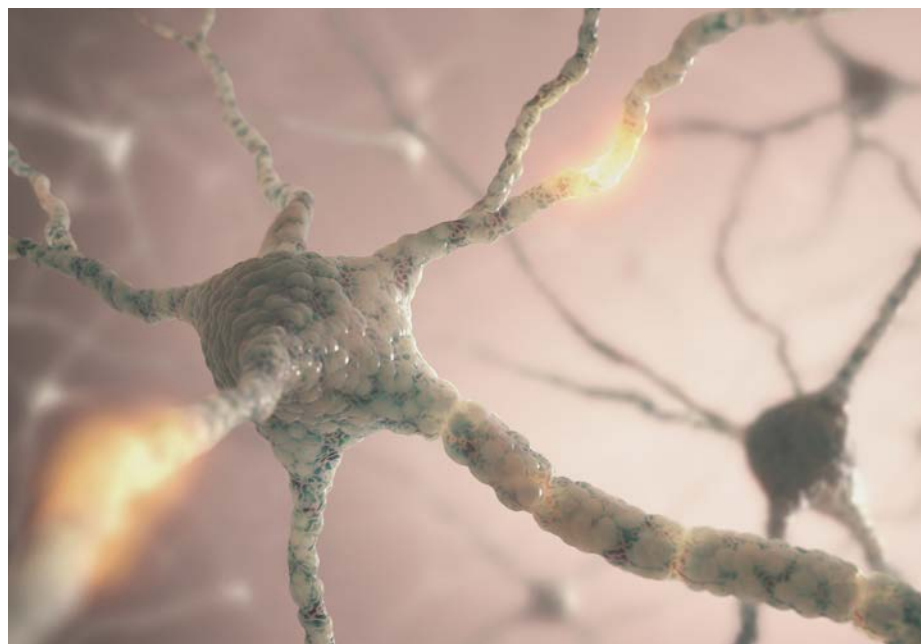
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Can a new light-based therapy help with Alzheimer's disease?

Prof Michael R Hamblin of the Wellman Center for Photomedicine at Massachusetts General Hospital discusses a new light-based therapy for Alzheimer's disease

Alzheimer's disease (AD) and other forms of dementia are rapidly becoming the scourge of the 21st Century. In the 19th Century infectious diseases were the largest killer of mankind, while in the 20th Century, cancers and heart disease ruled supreme. However, significant advances made by the pharmaceutical industry gave us antibiotics to conquer most infections, while many newer drugs are now ensuring heart disease and even cancer are less often regarded as 'dread diseases' and more often thought of as manageable chronic conditions. Unfortunately, the same cannot be said about AD. Commentators seem to be constantly writing about 'the failure of the latest AD trial', whether the trial is an antibody that targets β -amyloid peptide or amyloid plaque for removal, or for inhibitors of β -amyloid synthesis in the brain. Society is concerned about the possibility of tens of thousands of old folks packed away in care homes or institutions, and whether relatives or the state will foot the bill for their possibly lengthy care.

What if the solution to Alzheimer's disease could be something as simple as shining a light on the head? While this extremely simple concept may initially seem to be very far-fetched, there does exist considerable evidence that it may indeed be highly effective, not



just for AD and dementia, but for Parkinson's, a range of different psychiatric disorders, and for brain damage suffered as a result of a head injury or a stroke. The idea of shining a light on the head has evolved from the approach known as 'low-level laser therapy' that was developed for wound healing about 50 years ago and has been used ever since for the reduction of pain and inflammation in orthopaedic conditions and injuries. Originally, red lasers (600-700 nm) were used, and then near-infrared (760-1000 nm) lasers were developed. The introduction of light-emitting diodes (LEDs) ensured that the therapy became much more accessible, since the price per mW came sharply down, and laser safety issues were no

longer a concern. Photobiomodulation therapy (PBMT) then became the newly-adopted international terminology for this intervention, as lasers were no longer required, and the term 'low-level' was considered to be confusing.

Advances have been made in understanding the mechanisms of action of PBMT including identifying the cellular chromophores (light absorbing molecules such as cytochrome c oxidase). The downstream effects include improved cellular metabolism (more oxygen consumption and ATP), reduced oxidative stress and inflammation, upregulation of anti-apoptotic and cytoprotective factors (Figure 1). Stem cells and progenitor cells seem



Figure 2: Vielight Neuro transcranial and Vielight Intranasal LED devices

to be particularly responsive to PBMT, and this accounts for its remarkable ability to heal and regenerate damaged tissues. When light is shone on the head, a small but significant fraction (~2-3%) penetrates the scalp and skull to reach the surface of the brain. However because brain cells (cortical neurons) contain a lot of mitochondria, they are highly sensitive to light, compared to the skin that has evolved to tolerate sunlight with no effects. Animal experiments have shown that PBMT can not only protect the brain against injury (stroke or traumatic brain injury) but can also stimulate the brain to repair itself by encouraging neurogenesis (formation of new neurons from progenitor cells), synaptogenesis (formation of new connections between existing neurons), and upregulation of the powerful neurotrophin, called 'brain-derived neurotrophic factor'.

Vielight Neuro

A variety of devices designed to deliver light to the head are beginning to appear in the marketplace, but one of the first and most effective is known as the Vielight Neuro. The Vielight Neuro consists of 4 clusters of

LEDs applied to different areas of the head, combined with an intranasal LED that is clipped inside a nostril (Figure 2). The wavelength is 810 nm and the total power is less than 100 mW. The Vielight Neuro has been designed primarily as a home-use device, and no adverse effects have been reported to date. The various LEDs have been designed to illuminate specific areas of the brain, namely the ventral medial prefrontal

cortex, the dorsal medial prefrontal cortex, the posterior cingulate cortex, the precuneus, the lateral parietal cortex, and the entorhinal cortex. These areas collectively comprise what is known as the 'default mode network (DMN)', an intrinsic brain network that can undergo an imbalance typical of many brain disorders including Alzheimer's disease. Margaret Naeser, an investigator at the Boston University School of Medicine and VA Boston Healthcare System, has found out that the delivery of NIR light to the scalp can have beneficial effects on brain function that can be measured by functional magnetic resonance imaging in chronic stroke patients. This includes increased functional connectivity among the cortical nodes of the DMN, and improved language was observed. Very recent investigation by Dr. Reza Zomorodi of the University of Toronto has shown that a single session of Vielight Neuro

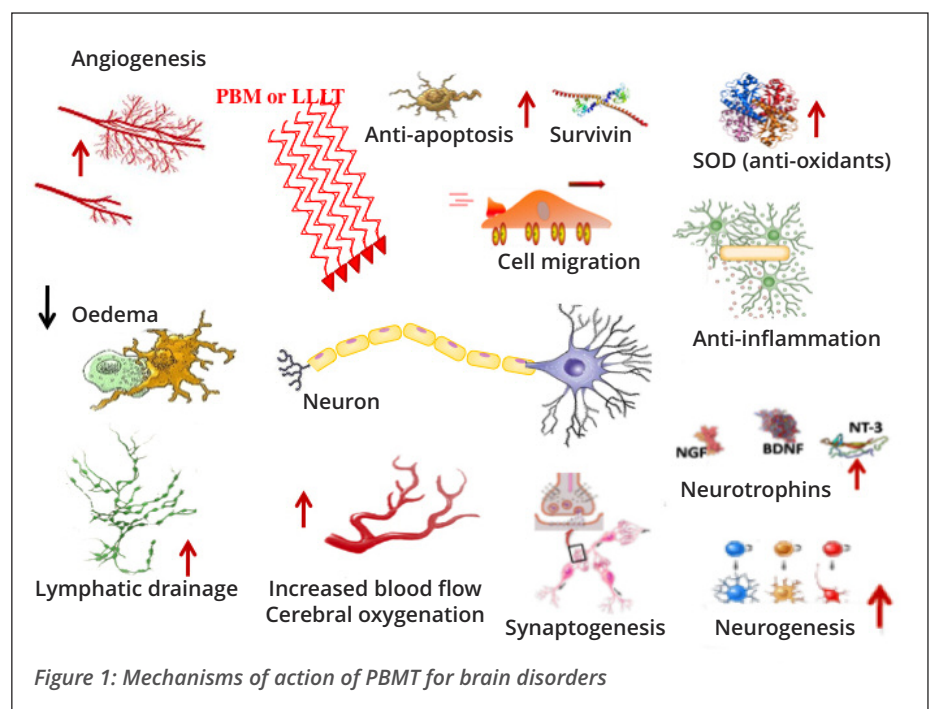


Figure 1: Mechanisms of action of PBMT for brain disorders

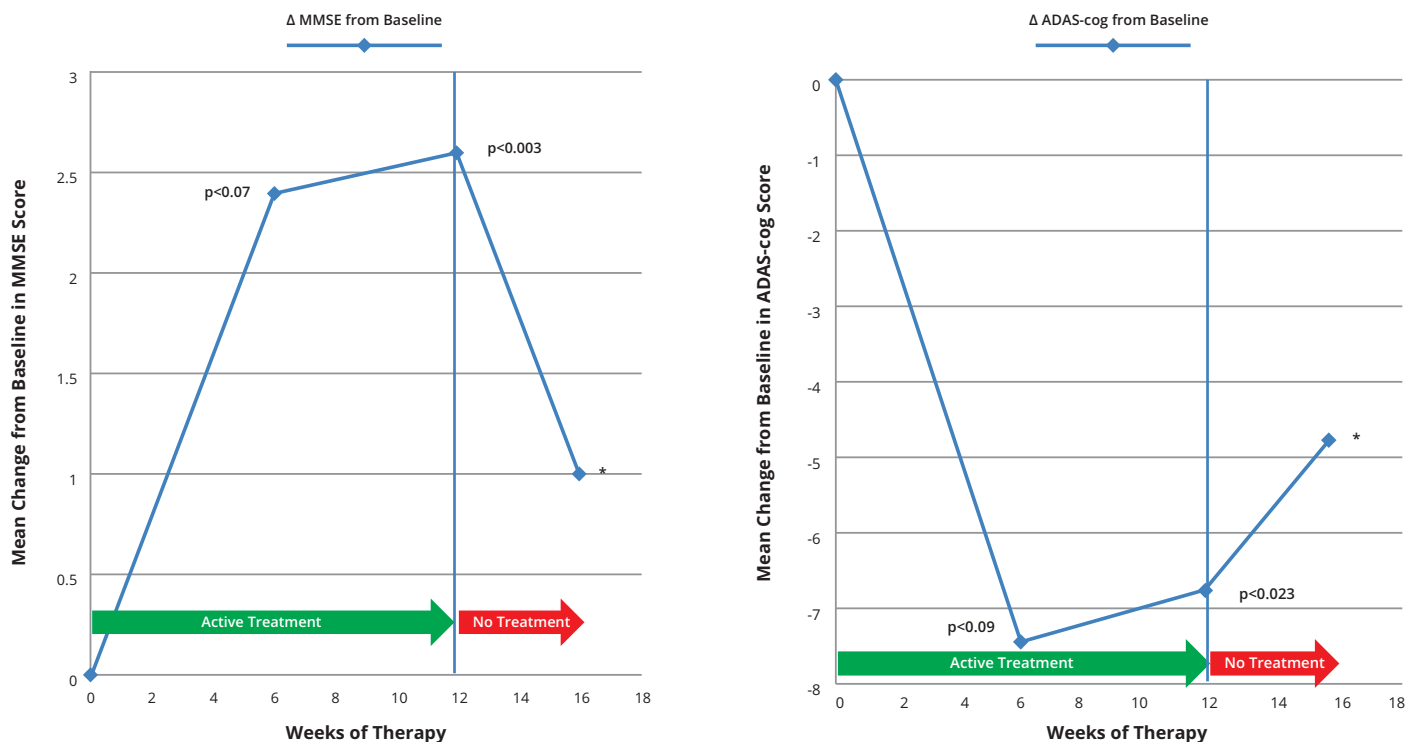


Figure 3: Results of PBMT clinical study for Alzheimer's disease. (A) MMSE scores. (B) ADAS-cog scores

* The p-value for Week 16 is omitted due to missing data from a patient who dropped out during the "4 Week No Treatment Period".

modulated cortical oscillation in a frequency-dependent manner in a double-blind crossover study for healthy volunteers.

A small trial of the Vielight Neuro was conducted in Toronto, Canada in patients who had been diagnosed with mild to moderate cognitive impairment due to dementia or AD. A group of 19 patients were initially randomised to receive real or sham PBMT, twice a week for 12 weeks of active treatment, followed by a 4-week period with no treatment. Most of the patients in the sham group dropped out of the trial before the end, leaving 5 patients who completed the active PBMT. These patients showed significant improvements in cognitive tests (MMSE, $p < 0.003$; ADAS-cog, $p < 0.023$) (Figure 3). The amount of improvement was 7 times larger than that found in the large clinical trial that

led to approval of Aricept (a reversible acetylcholinesterase inhibitor which is a common pharmaceutical treatment for AD). Increased functional status, better sleep, fewer angry outbursts, less anxiety, and less wandering were reported post-PBMT. Cognitive declines were observed during the 4-week no-treatment follow up period, but then subjects were given a device for home use and improved for the second time. Caregivers also started to use the device themselves. It is suggested that use of PBMT may act as a 'maintenance therapy' for AD sufferers and could provide many more years of good quality of life. Larger trials are in progress and are designed at the present time, and data is eagerly awaited on whether the improvements in cognitive function in AD patients treated with PBMT could be widely considered as approaching an effective treatment.

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Tackling the threat of antimicrobial resistance in Canada

As antibiotics become less effective against infection, Minister of Health, Jane Philpott, outlines the response to antimicrobial resistance in Canada

Antimicrobial resistance (AMR) is one of the most serious global health threats today. Existing antimicrobials, such as antibiotics, are becoming less effective as AMR is outpacing the development of new drugs to treat infections.

AMR happens naturally when bacteria that cause illness become resistant to the antimicrobials used to treat infections. However, inappropriate use of antimicrobials in health care, agriculture and veterinary settings can increase AMR. Resistant infections that are more difficult to treat can lead to long-term illness, increased healthcare costs and death. It is estimated that, with no action, annual worldwide human deaths attributable to AMR could reach 10 million by 2050¹.

Tackling AMR in Canada

Canada must be prepared to detect and respond to the threat of AMR to lessen the health risks to Canadians in the face of rising rates of drug-resistant infections around the world.

The Government of Canada created a Federal Framework and Action Plan, which has laid out the concrete actions we have been taking in recent years to address AMR and antimicrobial use (AMU). We are using a “One Health” lens with coordinated effort across human health, animal health and agri-food sectors, among others, to help prevent and control AMR.

We are strengthening surveillance systems to help identify new threats or changing patterns of AMR and AMU in humans and animals. For example, the Public Health Agency of Canada’s Canadian Antimicrobial Resistance Surveillance System integrates information about AMR and AMU in humans and animals to inform public health action. It draws on relevant data from both the human health and animal health domains



**Jane Philpott, Canada’s
Minister of Health**

through partnerships with specialised surveillance systems and laboratories.

Our government is strengthening the responsible use of antimicrobials in human and veterinary medicine, through the development of regulatory and non-regulatory initiatives, including public health guidelines, best practices and widespread communication to health professionals and the public. In May, Health Canada announced changes to the Food and Drug Regulations that strengthen rules to control access to veterinary antimicrobial drugs to better promote their prudent use in food-producing animals. Complementary measures are being developed to ensure that a veterinarian’s prescription will be required to obtain antimicrobial drugs for animal use. The Canadian Food Inspection Agency is also working with the animal feed industry to ensure prudent AMU through changes in the Compendium of Medicating Ingredient Brochures.

The government is also collaborating with national and international partners to advance policy, research and innovation in Canada and abroad. For example, the Canadian Institutes of Health Research (CIHR) invests in the Joint Programming Initiative on AMR, a global

research network made up of 23 member countries. CIHR is also investing in Canadian research teams that are developing innovative diagnostic tools to help clinicians quickly identify whether prescribing antibiotics will be effective.

Our Government plays a role in developing and disseminating information and guidance, and encouraging prudent AMU by public health and healthcare professionals, food producers, veterinarians and the Canadian public. Public awareness activities help Canadians to understand the benefits and risks of antimicrobials and why their use is not always warranted for treatment of infectious diseases.

“Our government is strengthening the responsible use of antimicrobials in human and veterinary medicine, through the development of regulatory and non-regulatory initiatives, including public health guidelines, best practices and widespread communication to health professionals and the public.”

Working with our Partners

Addressing AMR requires sustained efforts across multiple sectors and organisations. Provinces and territories, academia, animal and human health professionals, food production stakeholders and pharmaceutical and livestock industries each hold essential levers for reducing AMR.

A Pan-Canadian Framework for Action is being developed jointly with the provinces and territories and other key partners to guide our collective action in tackling AMR in Canada. This high-level Framework will identify strategic objectives, opportunities for action and desired outcomes under 4 pillars: surveillance, stewardship, infection prevention and control, and research and innovation.

Some key opportunities identified for future action include:

- Establishing coordinated ways to link AMR and AMU data from human health, animal health and agriculture sectors;

- Engaging all levels of government and stakeholders to deliver communication, education and training programs and tools on evidence-based infection prevention and control practices and strategies;
- Building knowledge about antimicrobial stewardship through enhanced and coordinated education for prescribers, dispensers and end-users of antimicrobials; and,
- Establishing a fast-tracked, cost-effective process for licensing antimicrobial drugs, alternatives to antimicrobials and new diagnostic tools in Canada to incentivise pharmaceutical investment without compromising safety, efficacy and quality.

Once the Framework has been completed, we will focus on developing an action plan that lays out concrete actions and timelines to meet the Framework’s objectives.

Looking to the Future

Significant work remains to be done to protect Canadians from the threat of AMR and to minimise the impact on human and animal health.

Everyone has a role to play and it is through collective actions that we will make real progress in tackling AMR in Canada and around the world. ■

¹ “Tackling Drug-Resistant Infections Globally: Final Report and Recommendations” The review on antimicrobial resistance chaired by Jim O’Neill, May 2016 https://amr-review.org/sites/default/files/160518_Final%20paper_with%20cover.pdf

Jane Philpott
Canada’s Minister of Health

Health Canada
www.canada.ca/en/health-canada.html
[www.twitter.com/HealthCanada](https://twitter.com/HealthCanada)



NSERC: Advancing science and technology in Canada

Open Access Government's M F Warrender highlights the work being undertaken by NSERC to pioneer scientific advancement in Canada

Science and technology are now driving forces within discovery and innovation sectors all over the world, with countries constantly matching and surpassing one another's technological advances. This has established a fast moving and cutting-edge platform for new innovations everywhere, and therefore constantly shaping the world we live in. Canada is one of these many countries on the brink of an exciting, dynamic, and prosperous future, as it refines its vision and further develops its Natural Sciences and Engineering Research Council (NSERC). The goal is to ensure that Canada can continue producing major discoveries and building upon the foundations of economic growth within a rapidly changing world.

The NSERC was formed in May 1978, and is an agency that provides grants for research in natural sciences and engineering. It is governed by a council composed of the President along with up to 18 members appointed from both private and public sectors. In June 2014, B. Mario Pinto was appointed the president of NSERC, and one year on from his election, he spoke of the NSERC's achievements, primary aims, and future plans. He stated: "NSERC creates value for Canada by investing in scientific inquiry and discovery research. This is at the core of NSERC's mandate. In doing so, we have established the powerful brain trust needed to fuel this country's knowledge-based economy." He also illustrated in detail the 5 clear goals that will be pur-

sued through his launch of NSERC 2020: a “strategic plan” to promote science and technology as the primary enablers in pushing Canada forward.

Key strategies for 2020

The 5 strategies established to push NSERC to where it wants to be in 2020 are:

- 1. Foster a science and engineering culture in Canada** (in order to make science and engineering mainstream, thus increasing interest, awareness, and appreciation of science as a way of experiencing, understanding and enriching the world).
- 2. Launch the new generation** (in order to enable early-career scientists to launch independent research careers).
- 3. Build a diversified and competitive research base** (to stimulate breakthrough research, and connect expertise across populations, institutions and sectors).
- 4. Strengthen the dynamic between discovery and innovation** (deepening interactions between its own partnerships).
- 5. Go Global** (in order to increase international research endeavours through the solidifying of Canada’s access to global scientific and engineering knowledge).

Thus far, the NSERC has built many strong partnerships across the research and innovation ecosystem in Canada, embracing and connecting the private sector, universities, colleges, government led research labs, training partners, and other non-governmental players. Students, in particular, play a vital role in fuelling research and discovery, and the NSERC provides many with industry experience and business skills, benefitting both the students and the industries themselves. It is important to note that 1 in 3 companies’ hire a student trained under NSERC partnership programs in Canada, and there have also been efforts to work with the research and development sectors of other countries worldwide. Most recently, as part of NSERC 2020 in

May this year at the 6th Annual Meeting of the Global Research Council, President Pinto finalised changes to strengthen collaborative research and training ties for students, with President of the German Research Foundation, Dr. Peter Strohschneider. This will create opportunities for student exchanges between Canada and Germany, maintaining a strong working relationship between the 2 countries. In Canada, 10,000 students trained each year in industrial settings, and increasing the levels of collaboration with other countries will without a doubt widen these students’ future opportunities.

Boosting Canadian research

Presently, countries all over the world are both competing and working together to maintain a prominent presence within this ever-growing sector. Through the NSERC, Canada is able to boost private sector research and development, and also focus on small and medium sized enterprises (SMEs), which, more often than not, have difficulty in making the transition into growth companies, and therefore use partnerships through the NSERC to scale up. Today, 97% of companies that have used NSERC’s partnership programmes would recommend them to others, and NSERC 2020 will continue to further improvements through its set of goals. However, its aims are perhaps best summed up by the president himself: “It seeks to maximize the efficacy and extend the reach of existing tools, while also taking advantage of new modalities. With the new strategic plan, NSERC 2020, we can contribute to positive change.” ■

M F Warrender

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The development of low-permeability hydrocarbon resources

Professor and NSERC/Chevron Industrial Research Chair, David W. Eaton, talks about the need to ensure hydrocarbon resources are developed responsibly

Fossil-fuel supply chains have been radically altered by the unprecedented development of low-permeability hydrocarbon resources (LPHRs), especially North American shale gas, tight oil and, more recently, liquid-rich shale plays. Access to these vast low-permeability hydrocarbon energy resources has been driven by new technologies, primarily massive, multi-stage hydraulic fracturing and long-reach horizontal drilling (Figure 1). The deployment of these disruptive technologies has, to a large extent, outpaced the advancement of fundamental scientific understanding of underlying physical processes as well as the capacity of agencies to implement science-informed regulations.

How can economic, environmental and social considerations be brought to bear on these complex issues? The concept of responsible development entails an holistic approach in which environmental, economic, and social considerations are integrated, based on transparent, science-informed regulations that inspire public confidence. This article applies this philosophy to key aspects of scientific research and training of highly qualified personnel that are essential for the responsible development of LPHRs, within a framework that embodies the need to reduce environmental impacts as well as resource intensity.

Improved efficiency

Commercial extraction of LPHRs is

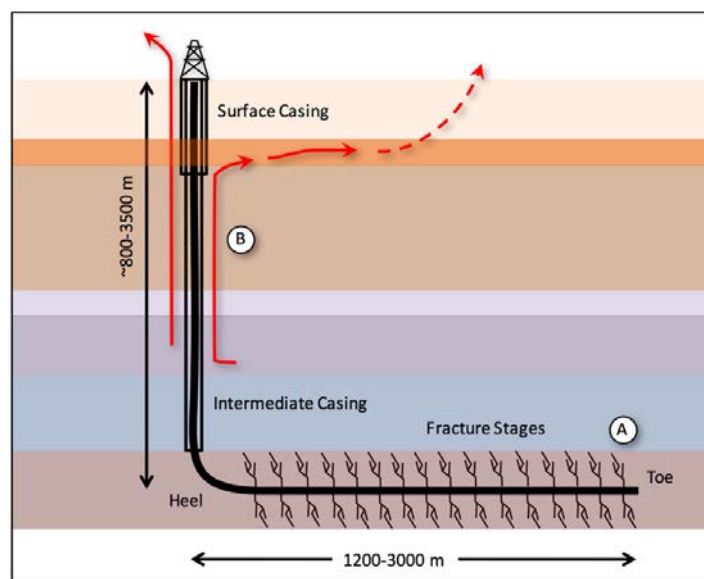


Figure 1: Schematic illustration of multi-stage hydraulic fracturing in a horizontal well (not to scale). A. Research on completion optimization includes monitoring and controlling fracture height and focusing stages on 'sweet spots' to reduce resource intensity. B. Possible contamination pathways, shown by red arrows, include gas leakage along the casing and/or microcracks in the cement. Fugitive emissions may travel horizontally within near-surface layers or escape into the atmosphere

enabled by drilling of horizontal wellbores that are completed in multiple stages using massive (typically water-based) hydraulic-fracture stimulation treatments. Current practice in the unconventional oil and gas industry uses a 'factory' design philosophy with uniform spacing of stages along the wellbore and is trending toward increasing the number of fracture stages along the wellbore with increasing the net injected volume. Further, horizontal laterals are being placed closer together in the horizontal plane, and vertically in the development of "stacked" LPHR plays. This trend places enormous stress on resource utilisation, including water use and the energy required for resource extraction. Research is currently underway

to support the development of enhanced fracture-design and surveillance technologies, based on new geophysical, well-test, and geochemical imaging techniques combined with laboratory measurements of reservoir properties, displacement phenomena, and modelling through digital core analysis. The goal of this research is to develop a more efficient approach that combines reservoir ('sweet spot') targeting with improved fracture surveillance and numerical simulation methods, such that less intensive but more effective hydraulic fracturing stimulation can be achieved.

Environmental impacts

Natural gas derived from LPHRs is sometimes promoted as a cleaner fuel

that could enable a smoother economic transition away from coal and towards renewables. The effectiveness of this strategy, however, depends upon the amount of methane emitted into the atmosphere ('fugitive emissions') from resource extraction processes and delivery to the customer. Intensive use of hydraulic fracturing for LPHR development has also generated public concerns regarding the potential contamination of surface waters, groundwaters, and soils. These concerns arise from the potential for groundwater contamination due to fugitive gases that escape from the wellbore and/or contamination from flowback fluids containing saline formation waters and chemicals used during hydraulic fracturing.

A significant impediment to informed public debate is a general lack of quantitative data, including baseline groundwater data. Furthermore, knowledge is lacking concerning effective and scientifically defensible approaches for the accurate assessment of potential environmental impacts on shallow freshwater resources and the atmosphere associated with the development of LPHRs. Together with improved extraction efficiency, the acquisition of new data and development of improvement regional and local monitoring technologies are topics of ongoing collaborative research.

Induced seismicity

Earthquakes induced by activities linked to LPHR development have galvanised public attention. Despite vigorous research since the 1960's on the topic of injection-induced earthquakes, fundamental questions remain unanswered. For scenarios, other than hydraulic fracturing, the basic triggering mechanism of injection-induced seismicity is thought to be a pore-pressure increase within a diffusively

expanding region. Fault activation by hydraulic fracturing is more complex and even a basic understanding of the phenomenology requires improved knowledge of fracture and fault characteristics over a wide range of spatial and temporal scales. The challenge is exacerbated by the subtle expression of potentially active faults using existing imaging techniques. Finding science-informed solutions is an urgent priority for industry and regulators.

In Canada and elsewhere, regulations are largely based on ad hoc traffic light protocols (TLPs), which mandate operational changes (or complete shutdown) in response to uncertain observed parameters, such as computed magnitude and proximity of the event to the injection site. Provisions for TLPs have been developed by combining current industry best practice with trial-and-error; arguably, such an approach is not conducive to scientific innovation - or fostering of public confidence in the regulatory framework. Underlying this is the issue of how to mitigate and to manage risks of induced seismicity from hydraulic fracturing. Solutions will demand a departure from a business-as-usual approach to academic research.

Collaboration and interdisciplinary training

There are several common cross-cutting issues that need to be addressed in order to achieve the goal of responsible development of LPHRs. First, the development of improved scientific understanding needed to inform industry practices and regulatory frameworks, and to deal with complex associated socioeconomic issues, will require an open dialogue and extensive cross-sector collaboration between academia, industry and government. Moreover, the next generation of lead-

ers who are critically needed to implement the global energy transition must draw from an exceptionally broad interdisciplinary understanding of the relevant issues. Timely progress means that these leaders must possess both a depth of expertise developed within traditional science and engineering disciplines, together with a complementary breadth of experience working with business, legal and social-science paradigms.

Reducing the impact of fossil-fuel extraction

A fundamental transformation of global energy systems is essential in order to achieve the ambitious goals of the 2015 Paris agreement on climate change. Global energy demand is increasing; even with aggressive deployment of renewables, fossil fuels will continue to provide a major contribution to global energy supply over the coming decades. In its benchmark scenario, which accounts for policy changes to keep global warming to less than 2°C, the International Energy Agency forecasts a 30% growth in worldwide energy use by 2040, largely supplied by fossil fuels. There is, therefore, an urgent need to reduce greenhouse-gas emissions and other environmental impacts of fossil-fuel extraction.



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Measuring the impact of science and research in Ontario

Minister Reza Moridi explains how Ontario is bridging the divide between ideas and application when it comes to science and research

On Earth Day this year, more than 1.3 million people in 600 cities around the world marched to celebrate science and support its public funding. It was remarkable to witness these events because people don't usually get excited about science.

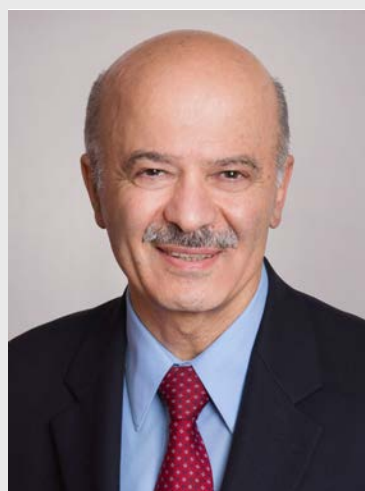
But citizens are increasingly worried that the global progress we have made in combatting the negative impacts of climate change will be destroyed in short order by a recent wave that rejects science as fact and advocates for a rollback in funding of scientific research. Science is under attack.

As an elected official in Canada's largest province, and as a scientist, I am deeply concerned with this trend. Governments have a responsibility to act in the best interest of their constituents by tackling the key challenges that impact everyday lives. Most importantly, this includes our health and the environment; but it also includes the economy, which bridges the divide between fundamental scientific ideas and their practical application.

Ontario is a haven for scientists. That's because we provide them with an environment in which they are free to push the boundaries of innovation. We support the full cycle of research – from the seeds of discovery to commercialisation and global market access.

Global leader

Ontario understands that a knowledge-based economy is the key to health and prosperity, and that scientific innovation and economic growth are closely linked. That is why the provincial government works hard to attract the best and brightest innovators and researchers from around the world, keep home-grown talent here and seize opportunities for global leadership.



Reza Moridi, Minister of Research, Innovation and Science

To build sustainable economic and social prosperity, Ontario has made strategic investments in:

- Supporting world-class research and scientists at Ontario's leading-edge institutions;
- Building and strengthening an entrepreneurial ecosystem to accelerate the start, growth and success of Ontario's innovative companies;
- Catalysing a stronger returns-based risk capital industry to support the growth and retention of Ontario's innovative firms, and;
- Ensuring that youth have the skills needed to excel in the modern economy.

Our combined investments have been mobilising and preparing Ontario researchers, entrepreneurs and firms to succeed, compete and create the jobs of the future.

We are making headway. The measured impact of Ontario research is well above the world average. With Ontario comprising nearly half of the research enterprise

in Canada, the nation ranks sixth in the world in quality and impact of research. As well, Ontario incubators/accelerators are ranked among the top in the world.

We are also in the process of hiring a Chief Scientist to help the government work smarter and better by relying on evidence and research, feeding the world's best ideas into government policies and programs. The Chief Scientist will formulate a long-term vision and strategic research agenda for Ontario that will help address future challenges and advance the scientific frontiers in Canada and around the world.

Collaborative approach

Ontario's universities, colleges, academic hospitals and research institutes are vital partners with government in ensuring the province remains at the forefront of the global knowledge-based economy. Ensuring that these facilities have modern infrastructure and consistent, predictable funding for research operations is the best way to facilitate the collaboration of businesses and researchers in critical economic sectors. Ontario's flagship research funding program, the [Ontario Research Fund](#) has 2 streams:

Research Excellence, which funds total direct and indirect research operational costs, with an emphasis on projects of significant impact to Ontario.

Research Infrastructure, which makes investments in cutting-edge research facilities and equipment.

Since 2003, the Ontario Research Fund has leveraged over \$3.8 billion in funding and helped create more than 103,000 training opportunities.

We also support scientists through the [Early Researcher Awards](#) program, which helps promising recently appointed Ontario scientists build their research teams. This world-leading, multidisciplinary program is investing in, generating and attracting a workforce with first-rate skills in science, engineering, creative arts, business and entrepreneurship.

Since the program's inception in 2005, Ontario has given 978 Early Researcher Awards to the province's leading early career researchers, invested approximately \$136 million in award recipients and leveraged over \$48 million in private and public sector partnerships.

This year, our support will help research initiatives such as:

- Improving brain flow and function after cardiac arrest;
- Developing cost-effective ways to recover metals and reduce the environmental impact of mine waste; and
- Evaluating the impact of social media technology on mental health awareness.

Since receiving his Early Researcher Award, Dr. Jason Fish, Scientist at the University Health Network's Toronto General Hospital Research Institute, has rapidly established himself as an emerging world leader in understanding how inflammation leads to heart disease. This research has established an entirely new paradigm in how cells communicate within the cardiovascular system. Dr. Fish continues to leverage his award to attract external funding, train research talents and translate the knowledge gained from his research to the clinic and marketplace.

I invite you to visit the [Ontario Ministry of Research and Innovation](#) website for more details on the work we are doing to sharpen our competitive edge.

By fostering scientific discoveries, including new technologies, treatments and cures for illnesses, Ontario is mobilising and preparing our researchers, entrepreneurs and firms to succeed, compete and create the jobs of the future. ■

Reza Moridi

Minister of Research, Innovation and Science

Ministry of Research, Innovation and Science – Ontario

www.ontario.ca/page/ministry-research-innovation-and-science

www.twitter.com/OntInnovation

Progressing health research in the North of Canada

Health Sciences North Research Institute shares the progress it has made in health research in Northern Canada, highlighting some of its major focus areas

The Health Sciences North Research Institute (HSNRI) is the affiliated research institute of Health Sciences North. HSNRI is designed to bring together researchers, clinicians, regional partners, and industry, and is founded on the basis of fostering translational research. HSNRI is a significant regional resource in health and biomedical research and has achieved recognition in many fields. HSNRI researchers are at the forefront of innovative and new discoveries, engaging our communities and implementing these discoveries through integrated knowledge exchange and reciprocal partnerships.

Our Research

The breadth and depth of health research expertise within HSNRI and its affiliated hospital provide the unique opportunity to merge initiatives and form collaborations that assemble stakeholders from the research community to address challenging and complex problems. HSNRI focuses on the following research priorities:

Northern & Indigenous Health

Our region is geographically and demographically unique with its numerous rural and remote communities. Northerners and Indigenous peoples face unique health challenges given the vast expanse of the region and issues with access to health care services and providers. As a result, people in this region have poorer health status and face unique challenges due to culture



and geography. Our Northern population health research focuses on the specialised needs of populations such as Indigenous peoples; those with chronic health conditions; and, those in rural and remote areas.

Healthy Aging

The Health Sciences North Volunteer Association Chair in Healthy Ageing leads this important area of research, which is designed to promote healthy ageing and vitality across the lifespan. The priority also focuses on the discovery of therapies and solutions for multiple conditions associated with ageing. This area of research works closely with the Infection & Immunity, Cancer Solutions, and Personalised Medicine programs to help improve the quality of life of Northern Ontarians and to other jurisdictions. It also intersects with the priority in Northern and

Indigenous Health to promote healthy ageing across the lifespan.

Cancer Solutions

Northeastern Ontario has significantly higher rates of cancer incidents and mortality than the rest of Ontario. HSNRI recognises a need for studying cancer, supporting cancer patients, promoting cancer research, and providing personalised treatment solutions. HSNRI supports these initiatives through the Tumour Biology research program, the Supportive Care Oncology Research Unit (SCORU), and the development of a Research Chair in Cancer Solutions to build capacity and support collaborations and partnerships.

Infection & Immunity

HSNRI's vaccine development and immunotherapy program is oriented

towards combating chronic and infectious diseases that are prevalent in many Northern communities. Specific infections currently under investigation by HSNRI scientists include *Clostridium difficile*, *Campylobacter*, and Influenza. Vaccines and immunotherapies will be designed not only to prevent disease but mitigate the disabling consequences of these illnesses.

Personalised Medicine

Personalised Medicine is an emerging technology that can be harnessed to research and treat many of the diseases that are more common in Northeastern Ontario. The goal of Personalised Medicine is to evaluate the unique genetic causes of each patient's illness, or predisposition to an illness, and tailor medical treatments specifically for each patient. Ultimately, person-centred approaches to understanding how values and context contribute to the clinical decision-making process will help improve health outcomes in the prevention and treatment of cancer for the people and communities of Northern Ontario.

Large Scale Collaborative Research Projects Population Health Ecosystem for Ontario's Northern and Indigenous Communities (PHEONICS)

The PHEONICS Platform will be Northern Ontario's first transformative research and development network built on a fully integrated cloud-based Information and Communications (ICT) platform. Connecting clinicians, patients, entrepreneurs, and leading academic and industry researchers, PHEONICS will accelerate the growth of an emergent health sciences research data cluster by offering access to a high speed data network and research infrastructure and contribute to the development, testing and application

of solutions for critical healthcare and economic challenges that are faced by our Northern and Indigenous communities. Within this context, HSNRI will create an innovation ecosystem of researchers, industry, clinicians, regulators and patients built on a high speed computer platform designed to stimulate research and development on health care priorities of direct interest and benefit to Northern populations, as a means to further the broader goals of Northern health equity and economic prosperity.

ICES North

The Institute for Clinical Evaluative Sciences (ICES) leads cutting-edge studies that evaluate health care delivery and outcomes. HSNRI is partnering with Laurentian University, NOSM, and ICES to develop a Northern-based satellite location. Hosting ICES North at HSNRI will help connect Northern researchers with valuable data and with world class researchers. Having a regional-based ICES satellite will also help attract new funding opportunities to ultimately help address the population health needs of Northern communities with a specialised focus on Indigenous health.

Walford Road Research Facility

This capital project was funded in part by the Greater City of Sudbury, the Greater Sudbury Development Corporation, NOHFC, and FedNor. Renovation of the former St. Theresa's school will provide HSNRI with approx. 32,000 sq. ft. of new research space. The facility opened in June 2017 and will help attract new talent in the health sciences cluster and provide state of the art space for our learners.

Solutions for the North, in the North, by the North

This is an exciting time for HSNRI as we apply our research strengths to

new initiatives, align our work with our affiliated hospital's health priorities, and steer HSNRI toward a prosperous future. We recognise and embrace a population health and health equity vision that intersects with the vast technological advancements at our disposal. This is evident through our cloud-based PHEONICS Platform and ICES North initiatives. HSNRI is now strategically positioned to lead the development of sustainable solutions to address the health care challenges faced by Northern and Indigenous Communities.

The people and communities of Northern Ontario are the key stakeholders and beneficiaries of our research enterprise. HSNRI initiatives and activities support the meaningful involvement of the people of Northern Ontario in identifying research priorities, designing and participating in research projects, and disseminating and translating research results to enhance health. HSNRI understands that interdisciplinary and collaborative approaches are mandatory in order to appropriately address the complex issues that impact health.



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Creating a highly skilled workforce for the future

Ontario's Ministry of Education shares why a highly skilled workforce is vital for progression and how this is being encouraged in the province

Building the Workforce of Tomorrow: A Shared Responsibility is the final report of the Premier of Ontario's Highly Skilled Workforce (HSW) Expert Panel. The report contains the Panel's final recommendations on developing a strategy to help the province's current and future workforce gain the skills needed to adapt to the demands of a changing economy.

The Province has since developed a Highly Skilled Workforce Strategy based on these recommendations. The Strategy includes specific direction for both the kindergarten to Grade 12 and postsecondary education systems in Ontario to support these changes.

What strategies are in place to ensure this happens and students are supported?

We've already made significant progress since the HSW Strategy was released. Moving forward, a new emphasis on global competencies and experiential learning will permeate the education system at all levels.

In addition to the HSW Strategy noted above, Ontario launched *Achieving Excellence: A Renewed Vision for Education in Ontario* in 2014. It focuses on what Ontarians view as essential outcomes for children and students through 4 goals: achieving excellence, ensuring equity, promoting well-being, and enhancing public confidence.

All of these elements are also present in Building the Workforce of Tomorrow: A Shared Responsibility, and have been carefully integrated into the implementation work of the HSW strategy. Similarly, the HSW strategy involves and builds on the existing work of a number of Ontario ministries, including the Ministries of Advanced Education and Skills Development, Education, Citizenship and Immigration, Economic Development and Growth, Infrastructure, and Indigenous Relations and Reconciliation.

How important is it for education to prepare students for the jobs of tomorrow?

Our government is working hard to give Ontario students the chance to develop strengths, interests and goals during their school experience – through programmes, such as Cooperative Education, Dual Credits, and Specialist High Skills Majors (SHSM). Starting in September, more than 50,000 students will be enrolled in almost 1,900 SHSM programmes. This represents 2,000 additional students and 108 new programmes for the 2017-18 school year. This is an innovative, high demand programme that lets high school students focus on a career path that matches their skills and interests while meeting the requirements of their high school diploma.

We are looking at ways we can expand experiential learning to provide all students from kindergarten to grade 12 with a broader range of learning opportunities outside of school that are connected to the community. These opportunities and the province's education and career/life planning programme are outlined in Creating Pathways to Success Kindergarten- Grade 12, which helps students to successfully make the transition to their post secondary destination.

Can you explain a bit about the career studies pilots and how they will enable this process?

Reviewing the guidance and career education curriculum on a priority basis is a key recommendation of the HSW report to ensure that it introduces students to a variety of learning pathways and opportunities.

The career studies pilots are in progress now until the end of this school year, as a part of the current grade 10 career studies course. The educators participating were provided with topics for the 4 modules on digital

literacy, career life planning, financial literacy and entrepreneurship, which they will customise for delivery with their students. Once the projects are complete, teachers will provide their final observations, about the impact of the project, the effect on student achievement and engagement, and artefacts of student learning. As these pilots are currently underway, it's important for us to review the data collected once they are completed to inform next steps.

This past November, Minister Hunter announced that financial literacy will be integrated into the careers studies course. Since 2011, we have invested more than \$3 million in financial literacy resources and professional learning opportunities for teachers to enhance financial literacy among Ontario's elementary and secondary students.

How will these be monitored?

Ontario's Achieving Excellence: A Renewed Vision for Education in Ontario includes a plan to monitor and evaluate our progress. Each of the renewed goals is accompanied by a "plan of action," as well as measures by which we will assess our progress toward each goal.

A variety of data and results from both internal and external sources contribute to knowing and understanding how our students are progressing towards the goals we've set out. Standardised tests, and assessments through EQAO, TIMMS and PISA provide a variety of evidence that inform our next steps. All of these contribute data that tell us how our students are doing in relation to the goals we've set out.

For instance, we launched our Renewed Math Strategy in the fall of 2016, based on solid evidence pointing to the need to improve student achievement in math. We are evaluating this strategy, as well as the results, to ensure that it is having the desired outcomes for student achievement. ■

Ontario Ministry of Education
www.edu.gov.on.ca/eng/
[www.twitter.com/ONeducation](https://twitter.com/ONeducation)

Non-Indigenous individuals' responsibilities within higher education contexts

Dawn Zinga, from the Department of Child and Youth Studies at Brock University explore the responsibilities of non-Indigenous individuals within higher education settings and the inequalities that exist

As a non-Indigenous scholar working in the area of Indigenous education, I spend a lot of my time thinking about my own role in perpetuating inequality within higher education and answering questions posed by non-Indigenous faculty, staff, and students. These questions usually fall into two broad categories. The first category consists of questions about why I am raising an issue or why something is important, while the second category tends to focus on questions about what individuals can do now, so that they know about the inequities that exist. These two categories of questions point to some interesting aspects about the responsibilities of non-Indigenous individuals' within higher education settings. One of the first responsibilities is to become educated about the realities of Indigenous peoples and related the systems of inequality. The second responsibility that I will focus on is what to do with the knowledge that you gain when you become educated.

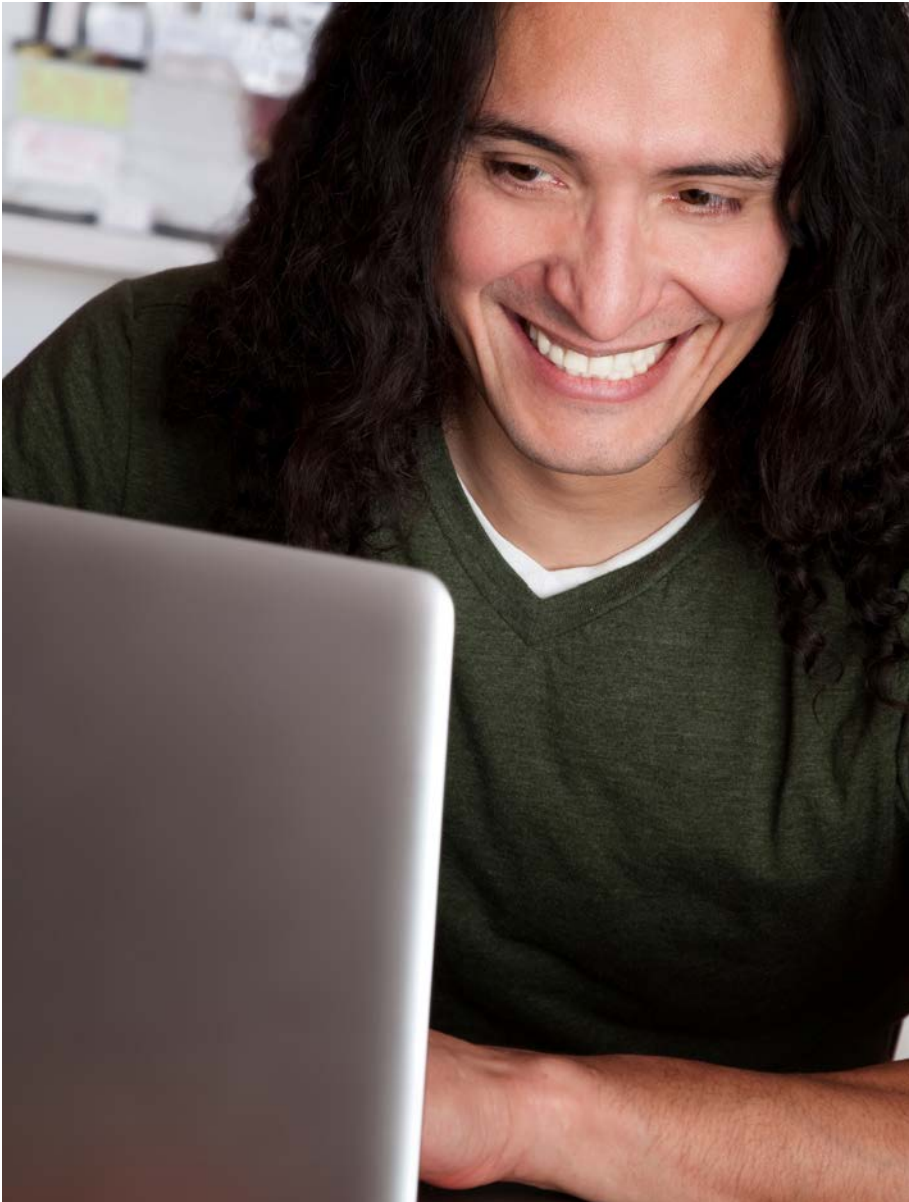
Starting with myself, I am a several-generations-removed immigrant to the ancestral lands on which I reside and I have experienced a position of some privilege in the mainstream structures of society, such as education, health services, and other governmental systems. While I grew up in a blue-collar home and experienced



the discrimination that can be associated with class and being a girl, I was afforded many privileges and rarely had cause to question that I belonged in the classrooms that I occupied. I frequently saw myself and my life experiences reflected in the classroom and my experiences within society. From a young age, I had a questioning mind and often challenged teachers about why some voices and some life experiences were not represented in the curriculum or were represented in very narrow and proscribed ways. Through my own search for knowledge and the generous teachings of my Indigenous colleagues, I became aware of the systems of racism and inequity experienced by individuals who are

minoritised by the mainstream systems of privilege and discrimination that continue to be reinforced throughout society and particularly within systems of education. In my role as a university professor, I am also responsible for exposing undergraduate and graduate students to these systems of inequity and to challenge their taken-for-granted assumptions.

Some of my students resist any challenges to their understanding of society and the status quo and remain facing the first responsibility of education. Other students engage in the teaching but sink into guilt and seem paralysed by the immensity and



complexity of the issues they have just learned exist. The second responsibility of what to do with the knowledge once you have learned it is easier to address than the resistance to learning that the world does not necessarily operate in a way that you thought that it did, and that with or without your knowledge, you have occupied a position of power and privilege. The first thing for non-Indigenous individuals to realise is that guilt is an emotion that will not be helpful. It must be experienced but in the end we are not responsible for the actions of those who preceded us, but we are responsible for how we address the legacy

that was left behind. Essentially, non-Indigenous individuals must focus on how to act on the knowledge that has been gained.

Non-Indigenous individuals have a choice. They can choose to close their eyes to uncomfortable realities and continue on perpetuating them or they can choose to use their individual voices to make a difference. Using one's voice can be as simple as speaking up when an inequality is being perpetuated, or challenging a policy that negates other people's experiences or lived realities. It can be exposing others to knowledge they

may not be aware of or supporting someone when that person's viewpoint is being shut down as invalid or irrelevant. Sometimes it can be listening to another perspective and being open to being challenged and educated about how your own actions or lack of action may have reinforced inequalities or alienated Indigenous individuals.

Addressing these two responsibilities within educational contexts can lead to educational settings in which Indigenous students and other Indigenous individuals feel welcome and accepted. It can open up important spaces to talk about ways of moving forward together towards positive change that does not reproduce or perpetuate systems of inequality. While I have focused on higher education contexts, this can also be extended to other educational contexts. Making a choice to address these responsibilities daily is a choice to move beyond resistance and guilt to positive action and strong relationships that can help us all negotiate a new future of education for all students.

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Supporting the urban Aboriginal population in Canada

Indigenous and Northern Affairs Canada explain how the organisation is working to better the lives of the urban Aboriginal population in Canada

Over the last 25 years, the urban Aboriginal population in Canada has been growing steadily. More than half of Indigenous peoples in Canada are believed to live in urban centres, which are considered to be an urban area having a population of at least 1,000 people and a population density of no fewer than 400 people per square kilometre.

Indigenous and Northern Affairs Canada works together to make the nation a better place for Indigenous and Northern Peoples communities. Supporting Indigenous Peoples (First Nations, Inuit and Metis), the department aims to: improve social well-being and economic prosperity, develop healthier, more sustainable communities and participate more fully in Canada's political, social and economic development – to the benefit of all Canadians.

Here the department answers *Open Access Government's* questions about how their programmes, including the new Urban Programming for Indigenous Peoples (UPIP) help to improve the lives of Indigenous and Northern Peoples communities.

How important is it to ensure that the lives of Indigenous people's in Canada are supported and improved? And how does the Minister work with communities to ensure this happens?

The Government of Canada believes it is vitally important to advance reconciliation with Indigenous Peoples through a renewed relationship based on recognition of rights, respect, co-operation and partnership as the foundation for transformative change.

The Government of Canada, through its last 2 budgets is making historic investments totaling \$11.8 billion for Indigenous peoples, in areas such as safe housing, clean drinking water, child and family services and

education, to address some of the root causes of poverty, ensure that Indigenous children receive the best start possible in life, and begin a renewed relationship with Indigenous communities. These investments are flowing to communities to help meet the needs of communities from coast to coast to coast.

The new Urban Programming for Indigenous Peoples (UPIP) prioritises improving the quality of life of First Nations, Inuit and Métis in urban centres.

We are also implementing the Truth and Reconciliation Commission's Calls to Action to redress the legacy of Indian Residential Schools and advance the process of reconciliation. To date, implementation of two-thirds of the Calls to Action under federal responsibility is underway. The Government of Canada is also working towards forging a new fiscal relationship that gives Indigenous communities sufficient, predictable and sustained funding.

How does the government support Indigenous peoples through programmes such as the new UPIP?

The new Urban Programming for Indigenous Peoples (UPIP) received Budget 2017 investments of \$118.5m over 5 years. Combined with funds previously allocated to the former Urban Aboriginal Strategy (UAS) programme, the government will provide \$53m each year to UPIP, beginning in 2017-2018.

What is UPIP designed to do and how will it help?

The Urban Programming for Indigenous Peoples supports organisations in urban areas that provide programmes and services for First Nations, Inuit and Métis. These centres are tailored to meet the needs of women, men, youth and families that live in particular



communities. For example, these organisations can offer navigator services (e.g. help navigating programs and services like health services and acquiring a driver's licence), land-based activities for youth, parenting programmes and other specific programs that help meet the needs of urban Indigenous peoples and support their transition to life in the city. The new programme will continue to support organisations in providing holistic and culturally-appropriate programmes and services to their clientele. Through UPIP, multi-year funding is now possible. Targeted funding to specific Indigenous groups is also a new benefit under the new programme.

Respecting language and culture are fundamental in giving all Indigenous people the best chance for success when living in or transitioning to an urban environment.

Why are programmes such as this crucial to help support people in more urban communities?

More than half of Indigenous peoples in Canada live in urban centres. Supporting First Nations, Inuit and Métis where they live is about improving quality of life and contributing to stronger economic growth in their communities, and in Canada. UPIP seeks to support

and build upon the existing network of Friendship Centres, which are working on the front-lines to address the numerous and often critical issues faced by Indigenous people in urban environments.

What is considered as an urban area? How much of the population does this include?

In the context of Urban Programming for Indigenous Peoples, an "urban centre" follows the Canadian census' definition of a "population centre": an urban area having a population of at least 1,000 people and a population density of no fewer than 400 people per square km. The Urban Programming for Indigenous Peoples applies mainly to large urban centres, but also to rural and northern areas that act as hubs for those living on reserves, or in smaller northern settlements. ■

Indigenous and Northern Affairs Canada
www.aadnc-aandc.gc.ca
[www.twitter.com/GCIIndigenous](https://twitter.com/GCIIndigenous)

All My Relations: advancing Indigenous family health

Dr Rod McCormick shares details on the All My Relations Network, a national Indigenous family and community wellness research centre for health and healing

Indigenous peoples of Canada are transforming research so it is now being done by us instead of being done on us. We are starting to use research to search again for what we once knew. This is an important and urgent search for us, as most Indigenous creation stories and traditional teachings provided us with guidance on how to lead a healthy life. As non-Indigenous Canadians celebrate Canada's 150 year birthday, Indigenous peoples of Canada acknowledge how 150 years of Canadian government efforts to assimilate us have resulted in our disconnection from the traditional knowledge that kept us healthy for more than 10,000 years. Failed efforts by the Canadian government to assimilate Indigenous peoples resulted in a disconnection from our sources of knowledge, strength, and wellness which were found in family, community, culture, the land and traditional spirituality. Currently there is a strong movement amongst Indigenous health researchers to reclaim that knowledge.

"The goal of this research centre is to establish a national Indigenous family and community wellness research centre to identify, research and further advance and implement best practices in Indigenous family and community health and healing."

Although Canada enjoys an international reputation as one of the worlds most admired countries, what is often



not known to other countries are the inequities that exist for Canadian Indigenous peoples. In the field of health alone there exists huge inequities in terms of disproportionate levels of illness and poor access to health care. As previously quoted in this journal, the Canadian Minister of Health summarised the gap in health-care by saying that if you are Indigenous your life expectancy is up to 10 years shorter than for other Canadians. For non-Indigenous health policy makers who often have a future oriented focus and hope that technology and western science will find the solutions to health care problems, it is difficult for them to understand why anyone would want to look to the past in order to guide present or future actions/solutions to existing problems.

To provide some context to this differing worldview, the Indigenous peoples of Canada's far north have encapsulated their experience, traditional knowledge, and wisdom into what is called Inuit Qaujimajatuqangit. It is their belief that this collected body of knowledge prepares Inuit for future success. Inuit Elders use the bow and arrow analogy to explain the relevance that these teachings have for the future. If you do not draw back the arrow in the bow, it will drop a short distance in front of you. Non-Indigenous people may understand this metaphor as a back swing as in golf or in tennis. The backswing is needed to generate the power to move an object forward. For Indigenous peoples the backswing involves activities where people review and identify past

resources, strengths, energy and accomplishments. Without gathering energy the arrow or the golf ball will not travel far. As our present becomes our past and our future becomes our present we recognise that cultural teachings and traditional medicine are always evolving to meet the challenges that we face. What we must not forget is that the connection we have to family, community, culture, the land and spirituality is what provides us with this source of knowledge. Unlike a western/European focus on the value of independence, Indigenous people's worldviews focus on inter-dependence or Interconnection. This philosophy is summarized by many First Nations in the expression: All my Relations. Our relations do not just refer to our family, communities and nation but to mother earth, sky father, grandmother moon, and our brothers and sisters in the plant and animal regions. "All my relations" also encompasses the spirit people – those who came before us and those not yet born.

All my relations

Thompson Rivers University (TRU) in British Columbia is located on the traditional unceded territory of the Secwepemc people. As an Indigenous Professor and BC Government health research chair at TRU, I am developing, along with Indigenous professors in Education, Social Work, Nursing, and Tourism a research centre called 'All my Relations'. The goal of this research centre is to establish a national Indige-

nous family and community wellness research centre to identify, research and further advance and implement best practices in Indigenous family and community health and healing. Although the centre itself does not yet have funding there are numerous funded research projects affiliated with All my Relations that address the reclamation of traditional healing ceremonies and practices, as well as a network for providing students and new investigators in health research with national and international opportunities to obtain mentorship in Indigenous traditional knowledge and medicine. The centre will be based on a number of core principles that will guide research that we hope will have an impact upon government policies in terms of Indigenous health care. Using the example of mental health, it is necessary for governments to shift their energies and resources from intervention and postvention to focus on prevention. This will require a shift to looking at a backswing or drawing back the bow. This leads to the second principle and that is that the solutions to preventing Indigenous mental health crises must come from the real experts i.e. those communities and Individuals who have successfully recovered from their own crisis. In general, governments within Canada must support Indigenous communities in their efforts to rediscover, reclaim, and to utilise the natural occurring healing resources, teachings and practices that have worked in the

past and that can be adapted for use in the present and in the future.

"Although Canada enjoys an international reputation as one of the worlds most admired countries, what is often not known to other countries are the inequities that exist for Canadian Indigenous peoples. In the field of health alone there exists huge inequities in terms of disproportionate levels of illness and poor access to health care."



Dr Rod McCormick

Professor and Research Chair

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Creating a modern transportation network for Canada

Marc Garneau, Minister for Transport in Canada outlines the importance of the transportation network for Canadian communities as well as the economy

As an exporting country, Canada strongly depends on the effectiveness and fluidity of its transportation network.

In order to create jobs, help the middle class and stimulate our economy and competitiveness, we must be able to count on a modern, integrated and effective transportation network, and we must invest carefully in it.

It must also be recognised that the network is under national and global pressure, and our adaptation will be essential for the future of the country.

Further to the recommendations of the Canada Transportation Act Review Report, I and Transport Canada representatives conducted a cross-Canada consultation to hear the views of Canadians, industry stakeholders, the provinces and territories, and Indigenous groups.

The information gathered allowed me to identify in depth the issues on which we must act in the short, medium and long-term, and the solutions to implement to resolve these issues. In November 2016, I presented my strategic plan for the future of transportation in Canada: Transportation 2030.

Transportation 2030 is a whole-system approach that ensures that all parts of Canada's transportation network work well together and support the actualisation of the government's general priorities.

Since this strategy was presented, we have begun to review the regulations and acts to amend in order to transform Canada's transportation network so that it better supports economic growth, job creation and the Canadian middle class.

Furthermore, in March, the Minister of Finance presented the 2017 budget, which includes initiatives and funding to modernise our transportation network.

Thus, on May 16, 2017, I tabled Bill C49, the Transportation Modernization Act. It represents a first legislative step to provide Canadians with a safe, reliable, clean and effective transportation network that will facilitate trade and travel while promoting environmental sustainability.

The tabling of the Transportation Modernization Act will allow Canada to take advantage of opportunities that arise on the international stage, contribute to a highly productive economy and respond to Canadians' needs and service expectations.

To do so, Canada will have to collaborate closely with the United States so that our activities take place seamlessly on both sides of our shared border.

As Canadians, we have always been aware of the challenges and privileges associated with such a vast country. To travel, we depend on roads, waterways, railways and airways. They connect us to our friends and families, to our work and to our leisure activities.

This important milestone will make our transportation network into one that can better serve Canadians. ■



Marc Garneau
Minister of Transport

Transport Canada
www.tc.gc.ca/eng/menu.htm
[www.twitter.com/Transport_gc](https://twitter.com/Transport_gc)

A new contactless payment solution for public transit

Contactless payment is benefiting Canadian transport systems, explains Louis-Martin Fournier, Product Manager at the Desjardins Group

More and more Canadians are using their credit cards instead of fumbling with cash. With all the new contactless payment technology available these days, it's easy to see why!

The shift away from cash has become even more pronounced in recent years, with a growing number of retailers offering contactless payment options, making it easier to pay by card, even for small amounts. Mobile wallets and apps have also contributed to fewer cash payments.

“We’re always looking for ways to make paying fares easier, and this includes our Monetico payment solutions. Our goal is to make it more convenient for commuters to take public transit by giving them more fare payment options.”

How is all this affecting transit companies? Today's commuters want more flexible fare payment options. Occasional commuters don't always have exact change or the time to purchase their fares in advance, so it's harder for them to take public transit. The gap between traditional payment methods and consumer habits is getting wider every year.

Commuters, who often use more than one transit system to get to their destination, are frustrated with having to pay separate fares for each system.



The new onboard payment solution makes it easier to pay fares – commuters are much happier and public transit is more accessible.

Desjardins and the Société de transport de Laval launch a pilot project

Desjardins has teamed up with the Société de transport de Laval (STL) and PIN Payment Solutions Inc., a company specializing in payment solutions in many different industries, to develop an innovative solution that will allow transit companies to offer contactless payment, enabling increased ridership.

A pilot project to test contactless payment was rolled out in April 2017 on several major STL bus routes. The preliminary results are even better than we had expected, and the new

payment option has been a big hit with commuters.

The proposed Monetico payment solution uses a contactless terminal that allows commuters to pay a single fare with their credit card or mobile phone when they get on the bus.

Transit companies around the world are looking to modernize and expand their fare collection systems to include alternative payment methods. The new payment solution being used in Laval buses is the first of its kind in North America, using EMV contactless technology.

The solution is designed to grow over time so that commuters can also purchase monthly passes, books of tickets and transfers for other transit systems.

"We are happy to be partnering with the STL to provide its clients with a payment experience that meets modern expectations and that contributes to broadening the payment offer for the public transportation industry," says André Chatelain, Executive Vice-President, Personal Services, Payments and Desjardins Group Marketing. "As one of the global leaders in payment systems, Desjardins is expecting this innovation, a first in Canada, to mark a major milestone in the integration of contactless payment into the various modes of transportation in this country."

"Today's commuters want more flexible fare payment options. Occasional commuters don't always have exact change or the time to purchase their fares in advance, so it's harder for them to take public transit. The gap between traditional payment methods and consumer habits is getting wider every year."

Desjardins has been meeting with transit industry stakeholders (private companies and transit authorities) since 2015 to promote its vision of onboard fare payment and the use of contactless payment terminals.

We're always looking for ways to make paying fares easier, and this includes our Monetico payment solutions. Our goal is to make it more convenient for commuters to take public transit by giving them more fare payment options.

Towards a simple, safe and fast solution

What we're working towards is a "tap and go" payment system that allows commuters to take public transit whenever they'd like. Commuters are going to be able to just hop on the bus, thanks to a fare payment tool

Benefits for commuters

- Easy "tap and go" payment system;
- Simple way to pay all the different transit fares;
- Similar to payment terminals used by retailers;
- Multi-system solution;
- No need to worry about having exact change;
- Ability to take the bus whenever you want;
- Fare payment by credit card or mobile phone.

Benefits for transit companies

- Easier for occasional commuters to take public transit;
- Faster "tap and go" fare payment;
- Better experience for commuters thanks to flexible payment options;
- Lower operating costs associated with fare payment.

Desjardins Group is the leading cooperative financial group in Canada and the sixth largest cooperative financial group in the world, with assets of \$272 billion. To meet the diverse needs of its members and clients, Desjardins offers a full range of products and services to individuals and businesses through its extensive distribution network, online platforms and subsidiaries across Canada. Counted among the world's strongest banks according to The Banker magazine, Desjardins has some of the highest capital ratios and credit ratings in the industry.

Monetico is the result of a commitment by Desjardins Group in Canada and Crédit Mutuel in France, with shared cooperative and mutualist values. Their goal is to create a range of payment solutions geared to both local entrepreneurs and large-scale, international businesses.

that lets them use their credit card to pay their fare.

As part of this evolving solution, Desjardins wants to:

- Include contactless debit cards as a payment option;
- Offer alternative payment methods for single fares and books of tickets;
- Round out the monthly pass offer by allowing commuters to use their credit card to take public transit;
- Link the different transit systems through intersystem transfers;

- Team up with partners, such as museums and tourist attractions, to offer package deals.



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Sustainability through technology: The power of N

Popularism and bumper sticker science should not stop us tackling sustainability through technology, argues Ingenuity Lab Director Carlo Montemagno

Ingenuity Lab is a unique organisation, designed and created to solve many of the grand challenges facing a modern world. Ingenuity Lab is a research organisation that focuses on the development and deployment of effective solutions to seemingly intractable challenges.

It works using a formal connect-and-develop process which involves building teams from members of government, industry, and academia. Central to this process is problem identification and the visualisation of the ideal solution. Often the identified problem is not the problem, but a symptom. Symptoms tend to be obvious, but quite often provide little insight into the most effective solution. With the recent intense discussion surrounding the newly imposed carbon tax in Canada, I think that it is time to extract ourselves from the emotion of the issue surrounding climate change, examine the impact of humanity on our environment, and identify the salient challenges needed to ensure global sustainability.

The unassailable fact is that the Earth's climate is changing. But the Earth's climate has been changing since its creation. The Earth's atmosphere, governed by complex, non-linear physical processes is easily perturbed. Changes in solar radiation, volcanic activity, deforestation, construction of cities and roads, large-scale irrigation and, yes, the release of CO₂ into the atmosphere, can all impact the Earth's climate. The

challenge is teasing out the climate variations caused by natural phenomena which we cannot manage from the impacts caused by anthropomorphic activities.

Firstly, we need to understand the impact of human activity versus natural processes on the climate. Then, isolate the impact of different human activities to further identify the effect that each activity has on the environment, especially when many of the activities occur simultaneously. For example, the change in albedo – the amount of solar energy absorbed/reflected – caused by the expansion of population centres is usually accompanied by an increase in CO₂ emissions. Which of the two impacts is more important? Are their collective impacts additive or multiplicative? There are many questions yet unanswered. If we cannot clearly define and quantify the “cause”, how can we craft an effective solution?

Disagreeing with Malthus

The bottom line is that human activity has impacted the Earth's environment since our society transitioned from hunter-gatherers. In 1798, Thomas Malthus postulated that humans were quickly going to exceed the carrying capacity of the Earth and that the positive population checks of starvation, disease, and war were necessary. He also dismissed the idea that technological advances in agriculture would provide the solution to the Earth's resource limits. I hear echoes of Malthus in much

of the dialogue surrounding climate change. While no one is proposing eugenic behaviour for addressing man's impact on the environment, there is a distinct tenor in the dialogue that humankind must accept a lower quality of life and reduced opportunity for future generations. There is also the implied truth that the human race cannot address the challenges associated with man's impact on the environment through advances in technology. I soundly reject both premises.

When I was growing up one of my favorite TV shows was *Get Smart*. I always waited for the moment in the show when Maxwell Smart would use his shoe phone. It was hilarious because most people perceived it as ridiculous. The concept of portable communication was outlandish. Nine years ago when Apple introduced the iPhone, it revolutionised global communication. In just 30 years, the technologies of science fiction fantasy transformed the way we engage in commerce, deliver healthcare, and interact as people. It effectively shrunk the world, making the Earth a single village where virtually every voice can be heard.

Popularism politics and bumper sticker science

Unfortunately, not every voice should be heard at the same volume. The cult of personality has enabled individuals without the requisite gravitas to seed popularism politics and bumper sticker

science. By feeding personal prejudices, rational discussion has been kicked to the curb and has been replaced by intensely polarised emotion. Culturally, Canadians have an intense connection to the environment. I believe that it is fair to say that the wonder of nature is strongly woven into the fabric of Canadian society. This is why Canadians feel compelled to lead the charge against global warming and why Canada has acted to impose a significant tax on the use of carbon. The question that many are asking, both inside and outside of Canada is, is this an effective path for addressing the global warming challenge?

Canada is currently responsible for releasing approximately 1.6% of all of the global CO₂ emissions. The European Union, China, India, Russia, Japan, and the United States are collectively responsible for releasing over 70% of the global CO₂ emissions. It is doubtful that even a 50% reduction of Canadian CO₂ emissions would have any material impact on global warming. To have any real effect on global warming, CO₂ emission reductions must occur in concert with all six of the major emitters. Even with over 10 years of significant effort, it has not been possible to achieve a meaningful coordinated global response to CO₂ emissions. Acting in isolation will only stress the Canadian economy and place an unnecessary burden on Canadians without achieving the desired goal of reducing man's impact on global warming. There is a better path forward.

We must recognise that humankind has impacted and will continue to impact the Earth. It is our responsibility to access the Earth's bounty in a sustainable way. Our ultimate goal should be to consume each of Earth's resources within cyclic processes to maximise the utility of all of the

resources that we harvest. The economic reusing of resources would ensure their continued availability for future generations. Achieving this vision can only be accomplished through technological innovation.

Examining the challenge of CO₂ emissions you find opportunity. Let's flip our perspective; instead of labeling CO₂ as a waste product we should recognise it as a valuable raw material. Carbon is the foundation, the building block of all living organisms. At the very core of the global ecosystem, nature uses the Sun's energy to assemble all living organisms from CO₂. Visioning the solution to CO₂ atmospheric emissions, suppose we can generically insert our industrial processes within the web of nature's carbon cycle. We take the CO₂ which would normally be emitted into the atmosphere, such as from an electrical power generating plant, and instead, using light, repurpose the CO₂ into valuable products. Effectively we insert the carbon that would have been wasted and transform it into the fabric of our society. Ingenuity Lab is currently commercialising this new technology.

Using the power of N – inspiration from nature to guide the manipulation of matter using nanotechnology to build networks – Ingenuity Lab succeeded in replicating the natural process of carbon assembly and translated it into an industrial process. The process required learning how to convert light into the various chemical fuels of life and the ability to cheaply fabricate nano-compartmented systems to assemble an artificial metabolism that fixes and transforms CO₂ into valuable products. While not the total solution to the global climate warming challenge, it does pull back the curtain to display the possible. It shows that the potential for technological achievement is boundless.

Advancing sustainability through technology

We must consider the past technological achievements of modern man as governments assess the optimum strategy for addressing global sustainability challenges. These achievements speak loudly about the human potential for creative innovation. Canada needs to occupy the position of a leading global steward of the environment, but must achieve it as a champion of sustainability through technology. It is the path forward.

Set the stage for a bright future for coming generations by embracing the potential of the possible, as well as understanding that technological achievement can drive market forces that lead to a more sustainable world. World leaders need to focus on providing an environment that supports the crafting of solutions to the global warming challenge and not at regulatory instruments as the primary weapon of choice. This strategy will accelerate economic and societal prosperity and has a much higher likelihood of long-term success. Canada, believe in the inventiveness and creativity of your citizenry. Provide the needed environment, and the people will deliver. The future belongs to the bold.

ingenuity lab

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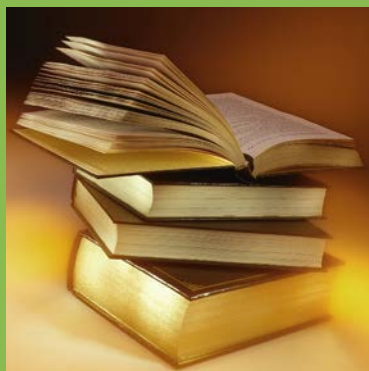
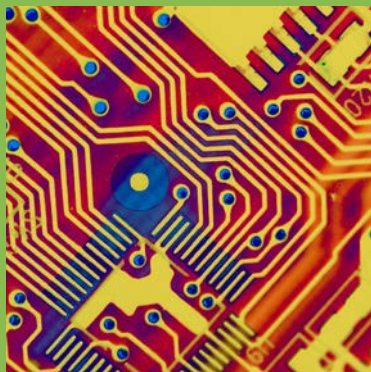
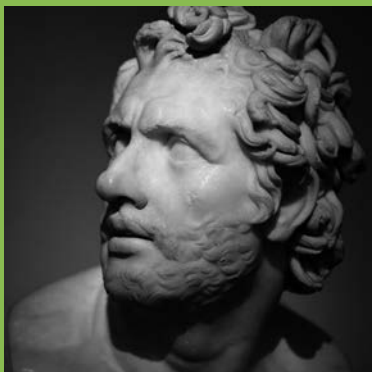


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