



Corporate Plan

GLOBAL CHALLENGES • GENOMIC SOLUTIONS



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SECTION I

About Genome Canada

enome Canada is a not-for-profit organization that acts as a catalyst for developing and applying genomics and genomic-based technologies to create economic and social benefits for Canadians. Genome Canada connects ideas and people across public and private sectors to find new uses for genomics, invests in large-scale science and technology to fuel innovation and translates discoveries into solutions across key sectors of national importance.

Around the world, countries are seeking the economic and social benefits that will come from leveraging research and innovation in the biological sciences. These benefits include improved health outcomes, boosts in productivity of agricultural and industrial processes, and enhanced environmental sustainability. The Organisation for Economic Co-operation and Development predicts the bioeconomy (all economic activity that is rooted in biology) will be worth \$1 trillion by 2030.

Canada is well-placed to capture its share and more of the bioeconomy, thanks to its ongoing investments in genomics - the science that examines the genetic code and the function of genes within the DNA of all living things. Reading and understanding the "code of life" is enabling the transformation of sectors that form the bedrock of our economy and social well-being, from human health, agriculture and agri-food to forestry, fisheries and aquaculture, energy, mining and the environment. Genomics is the engine that is driving Canada's bioeconomy.

Genome Canada catalyzes multidisciplinary research and innovation across sectors where genomics can contribute solutions. This provides clear opportunities for Canada to play a leading international role in emerging global issues such as antimicrobial resistance, climate change, increasing energy demand, population growth and an aging population.

Genome Canada excels in areas of human health genomics such as autism, rare diseases, cancer and infectious diseases. We have built world-class capacity for performing genomics research, which has positioned Canada as the leader in key areas such as the genomics of salmon, dairy cattle, conifer trees, wheat and flax. We provide Canadian researchers with access to the most advanced technologies as well as the tools to extract meaning from the influx of "big data," so that society can derive the benefits hidden within. And we are working to instill public confidence in these technologies and overcome barriers to their applications by fostering deepened understanding of the ethical, environmental, economic, legal and social aspects of genomics (GE3LS). Globally, Canada is ranked among the top three nations in producing GE³LS research. We have trained thousands of highly qualified personnel in genomics, who will be key in preparing the next-generation workforce to drive this country's future bioeconomy.

Since our inception in 2000, Genome Canada together with six regional Genome Centres have been at the heart of Canada's genomics enterprise – a complex yet collaborative network of individuals and organizations consisting of those who fund research, those who conduct it, those equipped to translate discoveries into applications and those who will use these discoveries to deliver benefits to, or derive benefits for, Canadians.

Backed by federal investments, Genome Canada and the Genome Centres have been the catalysts fuelling the enterprise and setting a national agenda for genomics in Canada. We lead Canada's genomics enterprise within a broader science, technology and innovation ecosystem. As the only agency in Canada with a singular focus on genomics – and its applications across multiple sectors of importance to Canada – we play a unique role in this ecosystem.

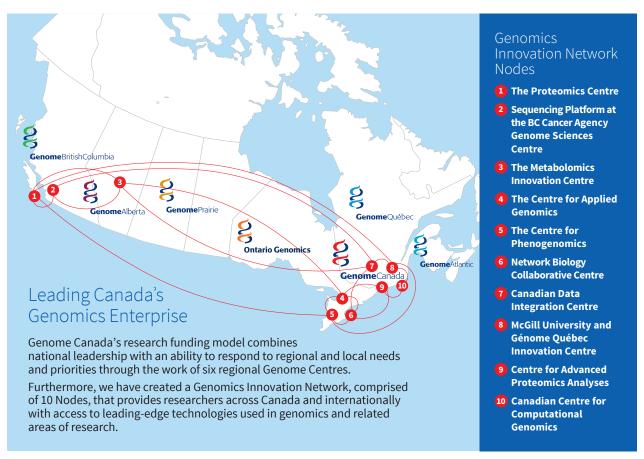


FIGURE 1: CANADA'S GENOMIC ENTERPRISE

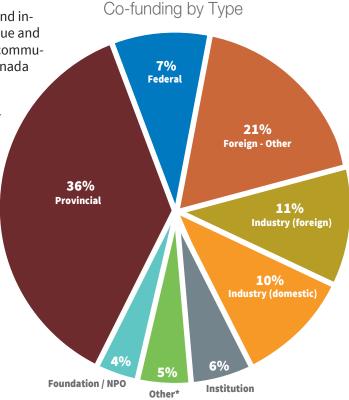
Through myriad partnerships and strategic program design, we ensure our alignment with key federal players such as granting councils, science-based departments and other federally funded not-for-profit organizations. We work with such entities to ensure a continuum of funding support across the entire life cycle of a research project – from discovery to application in the marketplace, health-care system and public sector.

Genome Canada's business model provides national coordination while setting strategic direction that is responsive to regional needs and priorities. Our upfront engagement with users of genomics ensures our research is more strategic and purpose-driven, with a greater likelihood of being translated into applications that solve challenges in all key sectors of our bioeconomy and across all regions of Canada. This Canadian focus is important because only in Canada will research be undertaken to address uniquely Canadian problems. These include the sustainability of the Alberta oil sands and Canadian mining sites, the productivity of our farms and forests in the face of climate change, and the improvement of health and economic opportunities in the Arctic and for Indigenous peoples.

Securing co-funding through partnerships is central to our business model. We bring together diverse partners to co-invest in Canadian genomics research for the benefit of our society. In collaboration with the Genome Centres, we have leveraged \$1.1 billion in federal funding since 2000 for a total investment of \$2.7 billion for genomics research in Canada.

Genome Canada is committed to increasing its co-funding ratio from the 1:1 ratio traditionally required for all past contribution agreements with the former Industry Canada (now Innovation, Science and Economic Development Canada) to 1:2 as requested in the next agreement. During 2015-16, Genome Canada has aggressively pursued partnerships with other organizations on initiatives that pursue similar innovation goals. The successful development of strategic national and international partnerships demonstrates that the value and strength of both the Canadian genomics research community and Genome Canada are recognized across Canada and around the world. Significant levels of private sector co-funding in Genome Canada's Genomic Applications Partnership Program (GAPP), industry engagement in Phase II of the Cancer Stem Cell Consortium and public-private partnerships are evidence of an increased interest in genomics from a wide range of industries.

As genomics has advanced and become ready to be translated into application in some sectors. Genome Canada and the Genome Centres have engaged productively with users in the private and public sectors, increasing their understanding of the value of genomics and motivating them to co-invest and collaborate with us at an unprecedented rate. Genome Canada has already witnessed notable commercial activity resulting from past research that we have funded in collaboration with the centres and our myriad partners. To date, more than 100 companies have been created or advanced due to the results of research funded by Canada's genomics enterprise. This has resulted in jobs and economic growth in Canada.



*Other category represents organizations that partner with Genome Canada to create a pool of funds up front to be applied to a specific competition or initiative (as opposed to participating as a project co-funder).

FIGURE 2: CO-FUNDING BY TYPE

Genomics is a maturing science and we are still very much at the beginning of the discovery process as the full power and promise of this cutting-edge field of inquiry starts to unfold. As technological advances accelerate, early demonstrations of impact become clear. Thanks to sustained federal funding and the achievements of researchers supported by Genome Canada, the regional Genome Centres and our partners, Canada is now a powerhouse in genomics. We are well poised to build on this success and place Canadian sectors at a competitive advantage globally through genomics.

Genome Canada's programs take discoveries from lab to society

Genome Canada supports the advancement of genomics in Canada. The knowledge generated through its funding programs supports evidence-based policy-making, strengthens Canada's bioeconomy and improves the quality of life for Canadians. Since its inception in 2000, Genome Canada has evolved its suite of programs to reflect both the rapidly changing state of genomics-based science and the opening up of opportunities across all sectors of the bioeconomy, driven by users of genomics technology in both the private and public sectors. Today, our portfolio of programs supports discovery research through to translation into application.

Large-Scale Applied Research Project (LSARP) competitions fuel the innovation pipeline. Through the LSARP program, Genome Canada supports discovery and applied research. It also encourages investigators to explore the potential uses of their discoveries by engaging with those who can help translate the research into applications that benefit Canadian society and the bioeconomy.

GAPP is an academic-user partnered program designed to:

- accelerate the translation of genomics research to application or market,
- promote the development of genomics-based solutions to address key challenges facing private and public sector users,
- create and foster a more productive interface between academia and users, and
- help mitigate risk for future investment from public and private investors.

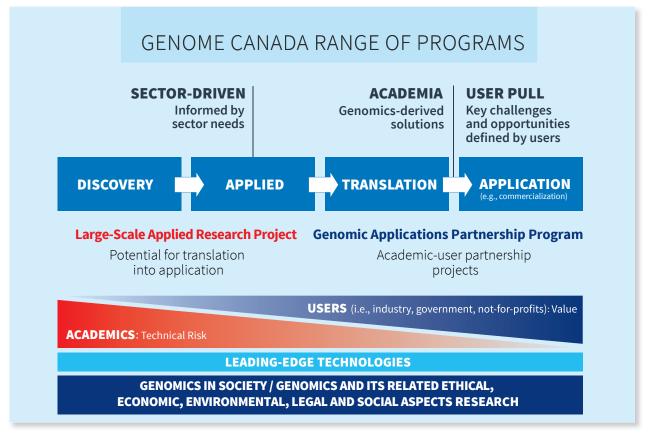


FIGURE 3: GENOME CANADA'S RANGE OF PROGRAMS

Underpinning our research funding programs are the technology programs, designed to provide Canadian scientists with access to leading-edge technologies, including bioinformatics and computational biology tools needed to manage, analyze and interpret the ever-growing amount of big data produced through genomic inquiry. Just as technology underpins the genomics scientific endeavour, so does understanding the broad societal implications of genomics research and its applications. Through its GE³LS program, Genome Canada supports the exploration of issues, such as what advancements in science and technology mean for our society, how public confidence plays into the effective development of genomic applications in Canada and how public policy can adapt accordingly, with the goal of identifying barriers to the uptake of genomics-derived applications in society early on in the process.

Commitment to accountability

In delivering its mandate, Genome Canada is committed to applying the highest standards of accountability and transparency to its operations, informing Canadians about the exciting opportunities and promise that genomics holds and reporting on results achieved. Mechanisms and instruments such as corporate plans and annual reports, independent performance audit and evaluation studies, peer review and research oversight committee processes, annual attest audits, continuous risk management assessment and effective oversight by the board of directors provide a high level of assurance. Genome Canada rigorously monitors its expenditures in order to manage operations in a fiscally prudent manner.

Governance

Genome Canada was established in February 2000 under the Canada Corporations Act and, in 2012, was issued new Articles of Continuance under the Canada Not-for-Profit Corporations Act.

Genome Canada is governed by a board of directors comprising up to 16 individuals drawn from the academic, private and public sectors. These individuals bring unique skills and experiences as well as strong interests and insights to successfully fulfil Genome Canada's strategic plan. Furthermore, the presidents of five federal research funding agencies – the Canada Foundation for Innovation, the Canadian Institutes of Health Research, the National Research Council, the Natural Sciences and Engineering Research Council and the Social Sciences and Humanities Research Council – are non-voting, ex-officio advisors to the board of directors.

The board of directors has overall responsibility for the stewardship of Genome Canada's business and affairs. To help with the discharge of these duties, the board has four standing committees: an executive committee; an audit and investment committee; a governance, election and compensation committee and a programs committee. As well, the board of directors has established a science and industry advisory committee. It provides strategic advice and approaches, and directions to help the corporation achieve its objectives.

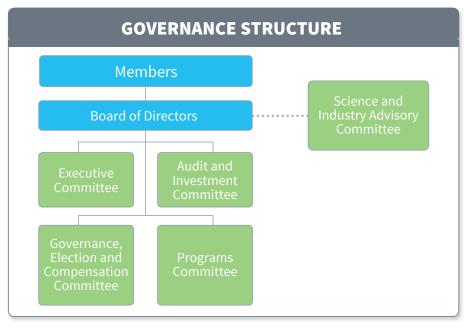


FIGURE 4: GENOME CANADA'S GOVERNANCE STRUCTURE

Strategic Plan and Performance 2015-16

n 2012, Genome Canada launched Genome Canada Strategic Plan 2012–2017, a new five-year strategic plan that included two new sectors, mining and energy. The new strategic plan reflected an important added focus for Genome Canada - namely, the growing influence of genomics as a transformative technology that will play a key role in addressing the most pressing challenges facing society in the 21st century. Genome Canada's Corporate Plan 2016-17 reports on the organization's activities and performance in fulfilling its strategic vision for the fiscal year 2015-16 and outlines anticipated activities for fiscal year 2016-17.

The corporate plan's reporting is organized around the three tenets of Genome Canada's mission statement and aligns with the organization's logic model with respect to stated outputs and outcomes.

Our Mission

Connect ideas and people across public and private sectors to find new uses and applications for genomics



science and technology to fuel innovation

Translate discoveries into applications to maximize impact across all sectors

FIGURE 5: GENOME CANADA'S MISSION

Genome Canada Strategic Plan 2012-2017

Vision

Harness the transformative power of genomics to deliver benefits to Canadians

Mission

To lead the Canadian genomics enterprise by:

- connecting ideas and people across public and private sectors to find new uses and applications for genomics,
- investing in large-scale science and technology to fuel innovation, and
- translating discoveries into applications to maximize impact across all sectors.

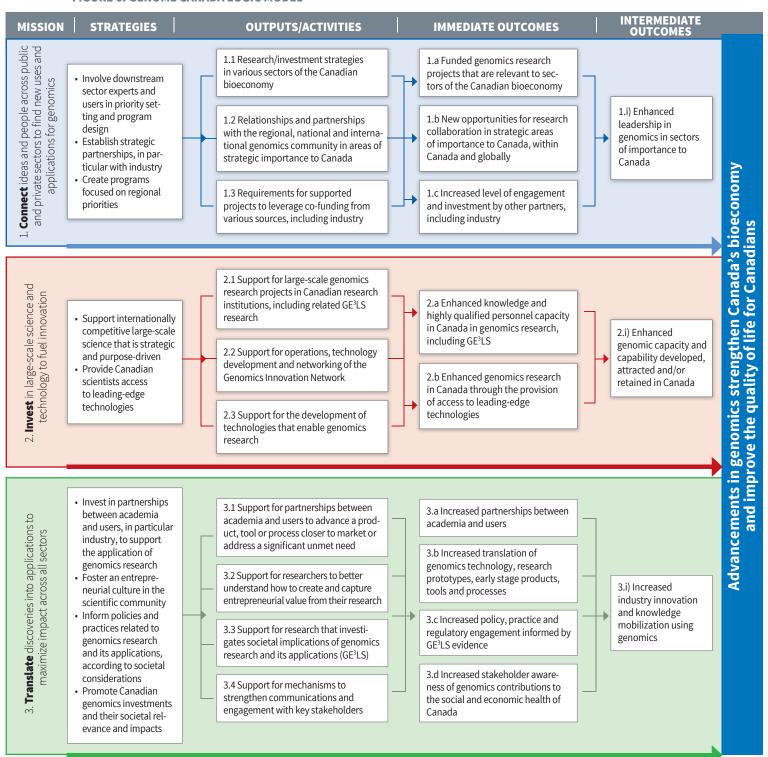
Objectives

- Respond to societal needs by generating genomics discoveries and accelerating their translation into applications.
- Attract greater investment in genomics research from a broad range of stakeholders, in particular the private sector.
- Enhance the impact of genomics by transforming knowledge of the ethical, environmental, economic, legal and social challenges and opportunities into sound policies and practices.
- Enhance the recognition of the value of genomics by increasing stakeholder appreciation of genome science, its applications and implications.

Logic Model

Genome Canada's logic model (see Figure 6) was built on objectives set out initially in Genome Canada's funding agreements and articulated in more detail in *Genome Canada Strategic Plan 2012–2017*. The logic model has been updated to reflect our submission to the 2016 federal budget. It demonstrates the core activities and outputs undertaken by Genome Canada and the Genome Centres, providing the reader with a clear road map of the outcomes and impacts that Genome Canada anticipates from the execution of its strategic plan. Details on how Genome Canada is performing against its strategic plan appear in subsequent pages.

FIGURE 6: GENOME CANADA LOGIC MODEL



SECTOR OUTCOMES

Genome Canada has placed more emphasis on the translational aspects of innovation by applying the knowledge gained from genomics research to grow the Canadian bioeconomy and address real-world challenges. Our programs and initiatives are purpose-driven, supporting research with the greatest potential for impacts that result in social and economic benefits for Canadians. This involves maintaining a balanced portfolio of funding for discovery and applied research to fuel innovation as well as funding for research that has matured to the translational phase. Our approach ensures alignment and complementarity with other key members of Canada's science, technology and innovation ecosystem to mutually reinforce our strategies and objectives and capitalize on synergies that can be derived from working together.

Outcomes in sectors of importance to Canada are beginning to be realized. The following section highlights some of these outcomes arising from our funding decisions.



Saving lives and improving health care through personalized medicine

Genomics is driving a paradigm shift from a disease-oriented health-care system to one that is more precise, personalized, predictive, preventative and cost-effective. Canadian genomics research has already led to saving lives, improving health outcomes and disease management for patients touched by cancer, heart disease, autism, epilepsy, rare diseases and other debilitating diseases.

Outcome examples

- A test being produced in Quebec to detect MRSA (a multi-drug resistant bacteria) is being used in more than 200 sites worldwide. The test can potentially reduce hospital-acquired infections by up to 70 per cent, with an average savings of \$2 million per site.
- More than 100 lives have been saved by the activation of defibrillators implanted in the chests of individuals who tested positive for a fatal gene responsible for Sudden Cardiac Death, thanks to the discovery of the gene by a Canadian team of researchers.
- Providing a diagnosis for their loved one's condition ended the "diagnostic odyssey" for more than 300 Canadian families of children with rare diseases. The CARE4RARE project made these diagnoses possible.
- A rapid diagnostic device is being used in the developing world for "point of care" diagnosis of tuberculosis and malaria.
- Pharmacogenomic tests are reducing adverse drug reactions (which lead to more than 20,000 deaths in Canada each year) by preventing codeine-induced mortality in infants, cisplatin-induced deafness and anthracycline-induced heart failure.
- A unique and world-leading open access public–private partnership that determines the structure of human proteins of therapeutic relevance to diseases such as cancer, diabetes and metabolic disorders is advancing drug development and faster entry into clinical trials.
- One in 68 children is affected by autism. Fortunately, genomics tools now exist to pinpoint dozens of genetic variants responsible for autism. These tools will make it possible to categorize autism into different subtypes, enabling earlier interventions, new treatment options and improved quality of life for these individuals and their families.
- Children across Canada with a form of brain cancer medulloblastoma are now being offered more effective interventions, limiting severe side effects and risks of over-treatment, thanks to the identification of markers that differentiate between brain tumour subtypes.

AGRICULTURE AND AGRI-FOOD



Generating competitive production systems and innovative products

Canada's agri-food sector employs some 2.2 million Canadians and Canada is among the world's leading exporters of food products. The agriculture and agri-food sector is well-positioned to use genomics to grow our share of the world's market as demand increases. Canadian genomics research is improving food quality, safety and security, and boosting production in crops and livestock. It is helping Canadians create high-value products, gain a more diverse global market share, increase exports and preserve and create jobs here in Canada.

Outcome examples

- The genetics of beef and dairy cattle have been boosted, resulting in improved productivity and value. Canada's dairy industry is realizing benefits of more than \$200 million per year through genomics-informed breeding for desirable traits.
- New traits are being incorporated in crops like spring wheat and barley, allowing them to withstand early and late frosts.
- The impact of diseases afflicting pigs are being reduced. These diseases together cost the Canadian pork industry \$100 million in losses each year.
- New strategies have been offered to make plants more resistant to spider mites, which currently cost Canadian farmers \$140 million in lost revenue yearly.
- "DNA barcoding" (i.e., using a very short sequence of DNA to identify an organism as belonging to a particular species) is preventing food fraud, managing pests and invasive species, and averting costly damage to crops. The United States Food and Drug Administration is using DNA barcoding to prevent fish fraud.
- A benchtop device that allows meat food processors to rapidly detect E. coli contamination is safeguarding food from contaminants and preventing lengthy and costly production issues.
- Understanding the genomics of grape ripening and yeast fermentation has helped improve wine quality and vineyard operations.
- High-value plant metabolites that have applications as pharmaceuticals, cancer drugs, industrial chemicals, etc. are being produced. One example is the development of a new Ebola vaccine that is produced in tobacco plants.

FORESTRY (A)

Making the sector more profitable and sustainable

Canada has one of the best conifer genomics platforms in the world and is well positioned to apply genomics-based tools to support the development of productive and healthy forests. Our research is helping to offset the impacts of pests (such as mountain pine beetle) and pathogens, boost forest productivity, monitor biodiversity and track invasive species for trees of economic importance, such as the white spruce and balsam fir. Further, it is seen as a powerful enabler in diversifying the forest industry from pulp, paper and lumber into a high-margin bioproducts-based industry.

Outcome examples

· Genomic screening has helped forest managers in Quebec select white spruce seedlings with increased growth characteristics and better quality wood, which will lead to greater productivity of the forest sector both locally and globally.

- An insect virus product was created to control the balsam fir sawfly in Newfoundland and Labrador. This could potentially save 25 per cent of useable trees in New Brunswick alone.
- Blister rust-resistance genes in western white pine have been identified and pollen from resistant trees has been used to create clean seedlings for coastal reforestation in British Columbia.
- Microbial communities developed for pulp and paper mills have reduced harmful bioproducts and produced power for operations, thereby making mills more efficient while increasing their social license to operate.
- "Enzyme cocktails" that degrade and convert biomass more efficiently have been produced, improving biofuel economics.
- New tools have been created to genetically improve poplar trees as a Canadian bioenergy feedstock.
- Genomics and climate mapping information have been drafted that is helping provincial forestry agencies in British Columbia and Alberta structure policy for tree planting to match the best tree seed to the environment, taking into account climate change.

FISHERIES AND AQUACULTURE



Enhancing production, protecting fish and ecosystems

Genomics is driving growth in the sector by helping to improve fish production, decrease loss from disease and pests, increase traceability and optimize feed formula for healthy, profitable and sustainable fish farms. Further, genomics offers powerful tools to monitor wild fish stocks for biodiversity, genetic origins and population health. It is providing critical information for the regulation of fisheries, leading to healthy and sustainable ecosystems.

Outcome examples

- Producers are enjoying a 20 per cent reduction in grow-out time for halibut because of genomic research results, which has led to a quicker time to market and greater profitability.
- A multi-year international collaboration involving Canadian researchers sequenced the Atlantic salmon genome, which has provided the foundation for the industry's use of marker-selected breeding.
- · Cooke Aquaculture, a major Canadian aquaculture company, will boost its growth and global competitiveness through the use of genomics tools that will select brood stock with desirable traits.
- Researchers have determined that the use of genetically modified Camelina a plant with high oil content - can be used as a partial replacement for fish oil and fish meal in aquaculture feeds where the current demand cannot be met with traditional methods.
- Researchers have identified the genomic signature associated with increased mortality in migrating Fraser River sockeye salmon, signalling that more research is needed on infectious diseases among wild stocks.
- Producers can now reduce losses in Atlantic salmon, armed with research that uses marker-assisted selection to develop strains of Atlantic salmon resistant to infectious pancreatic necrosis.
- Researchers have developed health assessment tools for marine mussels. These can also be used to indicate environmental stressors such as climate change and pollution.



Maintaining a clean, safe and sustainable environment

Genomics is equipping Canada to preserve a clean, safe and sustainable environment through the development of technologies to monitor and manage the effects of human and climate impact as well as invasive species. Canada is recognized for its global leadership in biodiversity science, breakthroughs in furthering understanding of economically and ecologically important trees, and development of new tools to de-contaminate polluted sites.

Outcome examples

- KB-1[®], a microbial culture used to enhance the cleanup of contaminated groundwater, was refined through Canadian genomics research and is the first product of its kind licensed in Canada. It is used at hundreds of sites worldwide.
- Genomics is being employed to assess and mitigate the environmental impacts of the Mount Polley Mine tailings spill in British Columbia.
- Genomics tools have been used in Alberta's Wood Buffalo National Park to assess biodiversity around the oil sands and produce a baseline upon which to measure the effects of the oil sands. Environment and Climate Change Canada is now using these tools in the Canadian Aquatic Biomonitoring Network.
- Tools to identify how organisms respond at a genetic level to toxic substances in the environment are being explored.



Providing tools to increase productivity in an environmentally sustainable way

Canada is the world's fifth largest oil producer. In 2014, the energy sector accounted for close to 10 per cent of the country's GDP. The sector can be advanced by integrating new genomics-based technologies into existing processes. For example, one of the greatest challenges is the amount of hot water used to extract bitumen from oil sands (the average ratio is 3:1). This is straining water and energy resources and generating considerable waste for storage in tailings ponds. Genomic knowledge of microbial processes involved in both hydrocarbon extraction and waste remediation is helping to improve the management of water use, recycling and treatment in the energy industry.

Outcome examples

- An energy company changed its plan of action based on knowledge that emerged (through the use of genomics tools) about risks caused by microbes in its tailings ponds.
- Microbes that are important in the processing of material extracted from the oil sands have been identified. Understanding the biological activity will allow for the development of more efficient processes.
- Microbes that accelerate corrosion of pipelines have been identified. This will enable the development of methods to control these microbes (killing the ones that cause corrosion). This makes pipelines safer.
- Understanding the role of microbes during liquid natural gas extraction provides information to develop sustainable processes and reduce impact on the environment.



Boosting Canada's outputs and advancing international leadership

Genomics research is underway in Canada that aims to improve industrial mineral extraction and processing. Further, genomics tools are providing new strategies to help manage and clean up contaminants, and control acid rock drainage and the unwanted leaching of metals. The applications of and opportunities for genomics in the sector are just starting to be recognized. This is a tremendous growth area for both research and industry.

Outcome examples

- Acid mine drainage is a common problem in mining sites. Genomics is being used to identify microbes that are involved in remediation, providing sustainable solutions to a huge liability for the industry.
- DNA barcoding, a genomics tool for assessing biodiversity, is being used by British Columbia mining company New Gold to evaluate the impact of its operations on the environment and develop sustainable processes.
- Microbes to leach metals from mine waste are being identified. A one per cent increase in the amount of metal retrieved before the waste is discarded would lead to millions of dollars in profitability for Canadian mining companies.
- Tools are being developed to monitor and improve mine drainage treatment.
- There is better understanding of the biological processes involved in the breakdown of pollutants at contaminated mining sites.

PERFORMANCE FOR 2015–16

The following sections highlight some of the significant outputs and outcomes from our ongoing work in 2015-16 as well as the intended outputs and outcomes of our newest initiatives. These include the 2014 LSARP Competition: Genomics and Feeding the Future, the Genomics Innovation Network, the 2015 Bioinformatics and Computational Biology Competition and Advancing Big Data Science in Genomics Research.

CONNECT IDEAS AND PEOPLE ACROSS PUBLIC AND PRIVATE SECTORS TO FIND NEW USES AND APPLICATIONS FOR GENOMICS

1 Involve downstream sector experts and users in priority setting and program design

Road maps or strategies were developed through extensive workshop consultations with key stakeholders for each of the following sectors: agriculture and agri-food, energy, mining, forestry, and fisheries and aquaculture. The sector strategies were used as engagement tools with key stakeholders and serve as road maps for Genome Canada's investments in each of these sectors. Key stakeholders include federal, provincial and regional governments, industry, sector-based regulators and policy-makers, and

researchers. Sector strategies were publicized extensively through activities designed to communicate and connect these sector strategies to the stakeholder communities.

As a result of the sector strategy development, Genome Canada's board of directors approved the development of request for applications for two LSARP competitions – one focused on Genomics and Feeding the Future, which was launched in June 2014, and one focused on Natural Resources and the Environment: Sector Challenges - Genomic Solutions, launched in 2015. Both competitions were informed by sector and user needs as identified through the sector strategy process. This ensured that key economic drivers would be targeted and that areas with a high potential for translation into practical applications would be emphasized.

Intended outputs and outcomes

- The breadth and depth of genomics knowledge in economic sectors will be increased.
- There will be positive impacts on policies, regulations, economic developments and quality of life.
- A broad range of stakeholders will boost investment in genomics research.
- Stakeholders will have a greater appreciation of the potential of genomics and its impact on society.



Partnerships are at the heart of our business model. In collaboration with partners, we synergize our activities to ensure genomic investments have the greatest impact and maximize the value of the Government of Canada's co-funding investment. We catalyze multidisciplinary research and innovation across sectors where genomics can contribute solutions, providing clear opportunities for Canada to play a leading international role in emerging global issues such as antimicrobial resistance, climate change, rising energy demand and a growing and increasingly aging population. Our work, in partnership with provinces, industry, national and international funding organizations, not-for-profits, Canadian institutions and others, has led to the emergence of a robust Canadian genomics enterprise that is delivering innovative solutions to the issues facing Canadians in a globally competitive environment. The successful development of strategic national and international partnerships is a demonstration that the value and strength of both the Canadian genomics research community and Genome Canada are recognized around the world. The following section highlights our significant partnerships and international consortiums.

International Barcode of Life: The International Barcode of Life project, led by Dr. Paul Hebert of the Biodiversity Institute of Ontario, is the largest biodiversity genomics initiative ever undertaken with the objective of constructing a DNA barcode reference library for multi-cellular life that will have practical applications in multiple areas. In the first phase of this project (2009-15), International Barcode of Life collaborators planned to barcode five million specimens representing 500,000 species. This technology has diverse applications. These include combatting food fraud, protecting endangered species, fighting invasive species, protecting ecosystems and making mining and other resource sector activities more sustainable.

Outputs and outcomes

In August 2015, Dr. Hebert announced that the 2009 targets for the barcode library had been achieved. The library now contains more than 5.8 million specimen records representing more than 500,000 species of animals, plants and fungi. It therefore already represents an extensive DNA barcode reference library that can be used for practical applications. For example, it can be used as part of biomonitoring initiatives to help halt the loss of biodiversity, one of the sustainable development goals adopted by the United Nations. Here are some of the project's significant outcomes.

- Regulatory agencies across the world continue to develop molecular barcoding as a
 tool to help identify quarantined and invasive species while enhancing the development
 of international collaborative networks to use barcoding for regulatory purposes. For
 instance, DNA barcoding is being used by Environment and Climate Change Canada as part
 of the Canadian Aquatic Biomonitoring Network and by the United States Food and Drug
 Administration to combat seafood fraud (the deliberate mislabelling of fish).
- Spurred by Genome Canada investment in the International Barcode of Life project, major barcoding investments were made in other nations such as Germany, Austria, Norway and New Zealand, increasing the extent of international research collaboration.
- The Barcode of Life Database has become the go-to biodiversity database and workbench. Users in more than 1,000 institutions from nearly 100 countries access it regularly.
- The Barcode of Life Database now includes a growing proportion of species equivalents identified by a new algorithm, RESL, developed at the Biodiversity Institute of Ontario rather than by traditional taxonomy, which cannot keep up.
- DNA barcoding is gaining acceptance as a standardized operational framework for taxonomic identification and is being recognized for its importance in helping to develop a global digital knowledge base for biodiversity. This is signalled by *Global Biodiversity Outlook 4*, the flagship publication of the Convention on Biological Diversity. It has incorporated information about DNA barcoding.
- The School Malaise Trap Program works with students and educators across Canada to
 explore arthropod diversity found in their schoolyards. Students are introduced to the
 life of a biologist and the science of DNA barcoding through comprehensive lesson plans.
 Started in 2013, the program brought a hands-on science experience to thousands of students across the country in 2015.
- A smartphone application developed in collaboration with SAP Software Solutions to crowdsource the collection and analysis of samples was first released in July 2014, along with a kit for tissue samples. This smartphone application, which is being further developed, allows anyone to collect a tissue sample or whole organism, send it off via smartphone for analysis (along with sample information) and get the species identified based on DNA barcodes. The number of participating labs in North America and Europe is growing.

Structural Genomics Consortium (SGC): The SGC is a not-for-profit public–private partnership that was established in 2004 to support the discovery of new medicines through open access research. Its core mandate is to determine the three-dimensional structures of human proteins of therapeutic relevance to diseases and to place them in the public domain so that industry and academia can have unrestricted use of them. The SGC collaborates closely with eight pharmaceutical companies to generate new chemical probes (inhibitors or other modulators of protein function) for the next generation of targets of therapeutic interest, focusing on epigenetic target proteins and protein kinases. The SGC, with the help of Genome Canada, recently developed a new partnership model that gives disease-specific foundations access to relevant chemical probes as they emerge from the

SGC pipeline. Disease foundations would also gain access to the SGC and industry scientists, thereby enabling discoveries to be translated into cures as rapidly as possible. This initiative first focused, as a pilot, on a partnership with the CHDI Foundation, which is dedicated to finding a cure for Huntington's disease. Negotiations are ongoing with six additional organizations. In its next phase (2015-20), the SGC will partner with clinicians and research hospitals to test the chemical probes in assays derived from patient samples. This approach will evaluate the proteins for their link to diseases (such as cancer) and inflammation, and validate them as potential targets for drug discovery.

The SGC is led by Dr. Aled Edwards of the University of Toronto and governed by a board of directors, which is made up of funders and chaired by an independent individual. The SGC is also advised by a scientific committee. The SGC has six locations: at the University of Toronto (Canada), Oxford University (United Kingdom), the University of Campinas (Brazil) and the Karolinska Institute, (Sweden) and in Chapel Hill (United States) and Frankfurt (Germany). The SGC received over \$60 million in funding for Phases I to III (2003-15) of its research from its pharmaceutical partners. These include GSK, Pfizer, Novartis, Lilly, Abbott Laboratories, Takeda Pharmaceuticals, Boehringer Ingelheim, Johnson & Johnson and Bayer. Phase III ended on June 30, 2015, and the SGC is now implementing a multi-faceted strategy to acquire funding for Phase IV (2015-20). It has secured funding to support the Oxford site, including \$18.5 million from the Wellcome Trust and \$11 million of cash and \$20 million in kind from industry (from Bayer, Janssen, Novartis and Pfizer) through the Innovative Medicines Initiative, which also contributed \$30.7 million. An additional \$30 million in industry funding (from Merck, Boehringer Ingelheim, AbbVie and Takeda) has been committed to the SGC and efforts are ongoing to secure public funding to support activities at the Toronto site.

The open and collaborative nature of the SGC enables all parties to do more science, with the ultimate goal of accelerating the path to drug discovery and bringing new and more effective medicines to Canadian patients faster and cheaper, attracting further investments to Canada from global pharma and reducing the costs of medicines to the health-care system.

Outputs and outcomes

To date, the SGC has been instrumental in delivering the following outputs.

- It has solved and deposited into the public domain more than 1,700 novel human structures (approximately15 per cent of the yearly and overall global output).
- The SGC's efforts have led to papers appearing in more than 900 publications, with roughly 27,500 citations (in 2015, more than 100 papers were published at a rate of more than two papers per week).
- More than 14 clinical trials in cancer were triggered by SGC discoveries.
- The SGC has solved and deposited structures of five human integral membrane proteins into public databases.
- The SGC has more than 250 active collaborations worldwide.
- The SGC has established partnerships with two disease foundations, Myeloma UK and CHDI Foundation.
- More than 7,300 samples of chemical probes have been distributed by SGC or sold by third-party distributors.

International Rare Diseases Research Consortium: Investments by Genome Canada and the Canadian Institutes of Health Research (CIHR) in rare disease initiatives such as FORGE, CARE for RARE and IGNITE make Canada a member of the International Rare Diseases Research Consortium, an international initiative on rare diseases. Canada is a key player in the consortium, chairing the executive committee and having leadership roles in the organization's diagnostic and interdisciplinary working groups.

Outputs and outcomes

- Since 2010, International Rare Diseases Research Consortium members have developed 158 new rare disease therapies, making excellent progress toward their goal of 200 therapies by 2020.
- A workshop was held October 2015 at the American Society of Human Genetics
 meeting to introduce Matchmaker Exchange to the scientific community. Matchmaker
 Exchange is a federated network of databases designed to identify genetic causes
 of rare diseases by matching similar phenotypic and genotypic profiles.
- Plans are underway to hold an international conference in late 2016 or early 2017 to coincide with the anticipated milestone of having developed 200 therapies for rare disease.
- A genetic test is available for nearly 3,500 rare diseases, up from 2,200 in 2010.

E-Rare-3: E-Rare-3 is the current project of the Europe-based ERA-Net for Research Programmes on rare diseases. It is a consortium of international funders that coordinates rare disease funding through transnational calls. From 2015-19, the consortium will extend and strengthen transnational cooperation between rare disease research funding organizations by building on the experience and results of ERA-Net's previous programs, E-Rare-1 and E-Rare-2. The consortium comprises 25 institutions from 17 European, associated and non-European countries. Its international dimension will lead to close collaboration with the International Rare Diseases Research Consortium and other relevant European and international initiatives.

Intended outputs and outcomes

- E-Rare-3 will encourage the pooling of resources available for transnational collaborations on rare disease research.
- It will increase knowledge about disease mechanisms and history in order to develop new diagnostic tools and treatments.
- It has strengthened collaboration between European research infrastructures such that projects can benefit from existing knowledge and services.
- Using increased knowledge and awareness, E-Rare-3 will influence decision-making, policies and action by partnering with patient organizations.

CIHR Research Catalyst Network – Rare Diseases: The Research Catalyst Network is establishing a national consortium to expedite collaboration between basic and clinician scientists in functional studies of novel rare disease genes. The network will identify instances where Canadian model organism expertise is relevant to a newly discovered disease gene. When such instances are found, a research project will be initiated to explore the functional characterization of the gene.

- This program, building on Canada's international reputation for being a leader in rare disease gene identification, will help extend the country's leadership to treatment and therapeutics for rare diseases.
- The work of the network will improve understanding of how specific gene mutations cause rare diseases. This will generate therapeutic leads and experimental approaches for further development.

International Mouse Phenotyping Consortium: The International Mouse Phenotyping Consortium is composed of 18 international research institutions and five national funders. The consortium has developed an internationally coordinated approach for phenotyping 20,000 mouse mutants. This produced the first functional catalogue of a mammalian genome.

Intended outputs and outcomes

- International coordination of mouse phenotyping research will increase, leading to a better understanding of human diseases.
- New genes will be discovered, with biological function ascribed to each gene.
- New ideas will be developed and evolving data annotation tools used to underpin future research into biological systems.
- With a centralized data centre and portal providing free, unrestricted access to primary and secondary data, collaborative networks will be maintained and expanded, and knowledge will grow.
- The consortium's centralized data centre will also promote an increase in knowledge and the development of tools by providing data, genotype-phenotype annotation, standard operating protocols and the development of open-source data analysis tools.

Cancer Stem Cell Consortium: The Cancer Stem Cell Consortium, a consortium of Canadian funders, aims to coordinate an international strategy for cancer stem cell research. The development of pan-Canadian research teams that work with industry will create knowledge and improve treatment of hard-to-treat cancers by targeting cancer stem cells.

The Cancer Stem Cell Consortium took part in a number of initiatives, including the following.

- The consortium's partnership with the California Institute for Regenerative Medicine resulted in the support of two multidisciplinary research teams, co-led by Canadian and Californian scientists. These teams are developing cancer stem cell-based therapy aimed at improving cancer treatment.
- The consortium partnered with the Terry Fox Research Institute to support a pan-Canadian project on adult glioblastoma multiforme.
- The consortium supported a project funded in the 2012 LSARP Competition on Genomics and Personalized Health. Led by Dr. Guy Sauvageau and Dr. Josée Hébert, the Innovative Chemogenomic Tools to Improve Outcome in Acute Myeloid Leukemia project is developing novel tools to comprehensively assess the relationship between genomic features and acute myeloid leukemia outcome. These assessments will be incorporated into clinical management strategies.

 The consortium partnered with Stand Up 2 Cancer Canada to support one pan-Canadian, integrated, cohesive project that brings together key stakeholders from across Canada to improve the outcomes of hard-to-treat cancers. The project is focusing on the consortium's role and stem cell programs concerning resistance and treatment failure in cancer.

Outputs and outcomes

- A polo-like kinase 4 inhibitor (CFI-400945) was developed and has been approved for clinical evaluation in the United States and Canada. This inhibitor has been shown to have significant anti-cancer activity in a number of solid tumours, showing promise for improved treatment. A Phase I clinical trial is underway to test this agent in advanced cancers.
- Two promising drug candidates AZD2014 and Disulfiram have been identified. This is an advance in personalizing treatment in glioblastoma, a deadly brain cancer that has eluded major treatment advances for three decades.
- There is now a more complete landscape of genetic aberrations and transcriptional dynamics in acute myeloid leukemia cells and improved clinical markers for this disease.

International Cancer Genome Consortium: The International Cancer Genome Consortium aims to coordinate large-scale cancer genome studies in tumours from 50 different cancer types and/or subtypes that are of clinical and societal importance across the globe.

Intended outputs and outcomes

- Systematic studies of more than 25,000 cancer genomes at the genomic, epigenomic and transcriptomic levels will reveal the repertoire of oncogenic mutations. Studies will also uncover traces of the mutagenic influences, define clinically relevant subtypes for prognosis and therapeutic management, and enable the development of new cancer therapies.
- Pediatric medulloblastoma studies could reduce overtreatment in children whose
 prognosis is good and improve quality of life for children whose prognosis is
 poor. The identification of biomarkers could allow for more accurate and reliable
 classification for treatment in randomized controlled trials. Identification of
 risk factors predisposing children to this type of cancer could lead to preventive
 measures.
- Studies of prostate cancer could increase knowledge related to inter-/intraprostate heterogeneity and identify factors that predict recurrence following surgery, radiotherapy and hormone therapy. Results of the study of prostate cancer tumour DNA could lead to more effective treatments.
- In collaboration with teams in Australia, work on pancreatic ductal adenocarcinoma will create models for validation and preclinical studies.
 Identifying the molecular mechanistic undercurrent behind the disease will provide opportunities to develop prevention, treatment and early detection strategies.

Canadian Epigenetics, Environment and Health Research Consortium (CEEHRC): The consortium was established through a partnership with CIHR and five of the Genome Canada-supported Genomics Innovation Network Nodes now play a key role in supporting the activities of the consortium. The establishment of this national consortium is a key knowledge translation function, designed to network together and expand on the previously funded research components.

Intended outputs and outcomes

- This consortium will promote collaboration between the technology platforms (Nodes) of Genome Canada's Genomics Innovation Network - sharing best practices, expertise and innovations.
- CEEHRC will facilitate knowledge translation functions.
- CEEHRC will network and expand on previously funded research components.
- CEEHRC will support the development and expansion of epigenetic research expertise in the country.

Canadian Institute for Advanced Research: The Canadian Institute for Advanced Research is a private, not-for-profit institute of advanced study that brings together unique individuals to focus on important questions with the potential to improve human health and the environment, transform technology, build strong societies, understand human culture and even chart the universe. As part of the Canadian Institute for Advanced Research's Global Call for Ideas, Genome Canada is collaborating on two network projects. The first is a research program to deepen the understanding of human microbiota in order to improve our understanding of human health, development and evolution. This program explores the role that the microbial organisms that reside within us (microbiota) have in human development and behaviour, and how the microbiota has impacted evolution and the dynamics of society and culture. New thinking in this emerging field will improve our understanding of personal and global health. The second program aims to answer the question, how can biology guide us in taking a leap forward in developing solutions for sustainable energy? This program's goal is to develop next-generation solar energy-harvesting science and related technologies for sustainable energy solutions. To do this, the program would take inspiration from the rapidly advancing fields of quantum biology and photobiology, with the potential for disruptive ideas in sustainable energy innovation.

Intended outputs and outcomes

- New knowledge will emerge about the role human microbiota play in development and behaviour, in addition to the effect on evolution and the dynamics of society and culture. This knowledge has the potential to change health practices and affect social policy.
- There will be new insights into biological systems: systems that self-replicate and selfpropagate to achieve ubiquitous solar-to-stored-energy conversion in plants and a near limitless variety of algae and photosynthetic bacteria. The goal is to improve the efficiency, cost-effectiveness and robustness of engineered solar conversion systems.

Global Alliance for Genomics and Health: More than 300 leading health-care, research and disease advocacy organizations involving colleagues in more than 40 countries have taken initial steps to form an international alliance dedicated to encouraging widespread access to genomic and clinical data. They are doing this by developing a common framework of international technical, operational and ethical standards needed to ensure the interoperability of genomic research platforms in a secure and responsible manner.

Intended outputs and outcomes

- Participants in a global alliance will develop a technology platform with open standards. This will create new opportunities to gain insight into disease, improve prevention and early detection, define diagnostic categories, streamline clinical trials and match patients to therapy.
- Rapid impact is anticipated in targeted therapy based on genomic characterization.
 Longer-term impact is expected through the discovery of molecular targets, leading to new and more effective therapies.

Sharing Big Data for Health-Care Innovation Competition – Advancing the Objectives of the Global Alliance for Genomics and Health: In order for Canada to take full advantage of the advances in DNA sequencing technologies for health care, we need to be able to share complex data sets, including genomic and clinical phenotypic data. These data need to be shared across institutional, provincial/territorial and national jurisdictional boundaries so that scientists and clinicians can interrogate disease-specific cohorts for validation, statistical significance and disease stratification purposes. There are a number of challenges associated with sharing genomic and clinical data sets, including the ad hoc use of a range of data formats and technologies in different systems, the lack of aligned approaches to ethics and legislation across jurisdictions, and the challenges of devising secure systems for controlled sharing of these data.

This competition supports Can-SHARE, a coalition of Canadian leaders of the Global Alliance for Genomics and Health, whose collective contributions to the mechanisms, platforms, policies and tools for wider data sharing have been integral to the success of the alliance. Together, this competition's applicants propose to advance Canadian leadership in the development of big data access and sharing efforts in Canada and within the Global Alliance for Genomics and Health. They will also strengthen their Canadian leadership role in other international research consortia such as the International Rare Diseases Research Consortium, the International Cancer Genome Consortium and the International Human Epigenome Consortium. The Canadian researchers leading this Can-SHARE application will be able to leverage existing and future sharing efforts through their involvement with the Global Alliance for Genomics and Health.

Intended outputs and outcomes

- It is expected that the program will leverage existing provincial/territorial and national genomic and clinical data-sharing efforts and be aligned with international initiatives.
- It will establish prominent Canadian leaders on the international big-data sharing stage, ensuring and enabling innovation in health care for Canadian patients.

3 Create programs focused on regional priorities

Genome Canada's emerging issues program provides up to \$250,000 from Genome Canada plus co-funding from other sources for 18 months to address opportunities or issues that are either newly arisen or whose importance have grown due to an increased incidence of the problem. Projects funded to date are usually in response to issues brought to our attention or initiated by a Genome Centre. Five projects have been funded thus far.

Listeria in the food industry

Project name: Application of Genomic Tools to the Detection and Surveillance of Listeria monocytogenes. Genome Canada partnered with the Canadian Food Inspection Agency, Alberta Innovates - Bio Solutions and Maple Leaf Foods to conduct genomics-based research into listeria.

Intended outputs and outcomes

- Project results will contribute to global knowledge on listeria. One of the project team host organizations, the Listeriosis Reference Service Laboratory, is a member of the World Health Organization Collaborating Centre for Listeria.
- A database of listeria genome sequences and genetic markers will be identified. These markers will be used to rapidly spot harmful listeria strains in foods and food-processing facilities.
- Faster and more cost-effective ways to screen food for the listeria bacteria will be created, which will bolster food safety for Canadians.
- Results will be published in the Compendium of Analytical Methods, a publication of Health Canada's Microbiological Methods Committee. This is a requirement for a method to be used for regulatory testing of foods or monitoring of food production facilities.

E. coli in the food industry

Project name: Application of Genomics Tools to the Detection of E. coli. Genome Canada partnered with the Alberta Livestock and Meat Agency through Genome Alberta, as well as with Alberta Innovates – Bio Solutions and the Ontario Ministry of Agriculture, Food and Rural Affairs, to explore ways that genomics tools can rapidly detect E. coli.

Outputs and outcomes

- Teams were successful in developing prototype tests for E. coli (the GenePOC STEC7 and cassette PCR tests). These are being further developed and expanded for additional use.
- · Additional funding was awarded through GAPP to expand the GenePOC test for use in the detection of other pathogenic bacteria.
- It is anticipated that this research will move current knowledge and techniques for rapidly detecting E. coli in the food industry toward the use of genomics tools. This will facilitate faster and more accurate identification, resulting in both health and economic benefits.

Porcine epidemic diarrhea virus

Project name: Program on Research and Innovation Leading to a Rapid Genomics Response to the Porcine Epidemic Diarrhea Virus (PEDv). Genome Canada partnered with Genome Alberta, the Alberta Livestock

and Meat Agency, the Canadian Food Inspection Agency, the Ontario Ministry of Agriculture, Food and Rural Affairs, and Ontario Genomics to support further genomics-based research into PEDv.

Intended outputs and outcomes

- The project aims to significantly reduce the impact of PEDv on the Canadian economy and pork industry. PEDv results in up to 100 per cent mortality in nursing piglets.
- The project will provide novel diagnostic and control strategies to infected farms and help protect others from infection.
- The project will improve diagnosis and industry control of PEDv.
- It will also improve the way industry responds to outbreaks.
- Molecular tools will be developed to help determine the feasibility of selecting resistant lines through genetic screening.

Mount Polley Mine tailings dam breach

Project name: Metagenomics to Assess Impacts of the Mount Polley Mine Tailings Dam Breach on Associated Ecosystems. Genome Canada and Genome British Columbia funded a project that uses metagenomic tools to assess the impact of the 2014 Mount Polley Mine tailings dam breach.

Intended outputs and outcomes

- The project will improve strategies for monitoring the impact of the Mount Polley Mine tailings dam breach on the ecosystem and providing recommendations for environmental remediation.
- The project will determine the likelihood of long-term metal leaching into the watershed.
- Tools for monitoring passive bioremediation in soil and water will be improved.
- Molecular markers of metals removal and soil rehabilitation will be developed.
- The project will conduct controlled bioaugmentation/biostimulation trials.

Avian influenza virus surveillance

Project name: Genomic Analysis of Wetland Sediment as a Tool for Avian Influenza Virus Surveillance in Wild Waterfowl. Genome Canada and Genome British Columbia funded a project using genomic approaches to collect sediment samples from wetlands and areas where migratory birds congregate to develop a genomics-informed prediction protocol for avian flu (H5N2) outbreaks in domestic poultry operations.

Intended outputs and outcomes

- Research into potential pathogens and prediction protocols could significantly reduce the effects of the avian influenza virus on the Canadian economy and poultry industry.
- Better tools will be developed to predict future outbreaks and will be used as an early warning system for the arrival of dangerous influenza viruses in British Columbia's Fraser Valley and elsewhere in Canada.

INVEST IN LARGE-SCALE SCIENCE AND TECHNOLOGY TO FUEL INNOVATION

4 Support internationally competitive large-scale science that is strategic and purpose-driven

2015 LSARP Competition: Natural Resources and the Environment: Sector Challenges - Genomic **Solutions**: The 2015 LSARP Competition sought to support applied research projects that used genomic approaches to address challenges and opportunities of importance to Canada's natural resources and environment sectors, including interactions between natural resources industries and the environment. Solutions will contribute to the Canadian bioeconomy and well-being of Canadians. The scope of this funding opportunity includes areas such as genomics research related to energy, mining, forestry, water stewardship, wildlife management/conservation and bioproducts that will help conserve natural resources and protect the environment. Funding decisions and project start-up will occur in 2016.

Intended outputs and outcomes

• The projects' outcomes are expected to address challenges and opportunities related to the conservation of natural resources and protection of the environment. Outcomes have the potential to contribute to the Canadian bioeconomy, environment and well-being of Canadians.

2014 LSARP Competition: Genomics and Feeding the Future: The 2014 LSARP Competition supports projects that use genomic approaches within the agriculture/agri-food and fisheries/aquaculture sectors to address challenges and opportunities related to global food safety, security and sustainable production. Using such approaches would contribute to the Canadian bioeconomy and well-being of Canadians. Funding flowed to projects in 2015.

Projects funded

Enhancing production in coho salmon: Culture, community, catch

This project's team is developing and using new genomics tools to address challenges facing the safe. secure and sustainable production of coho salmon. The team is sequencing the coho salmon genome, documenting the genetic diversity of thousands of individuals and determining how coho salmon from different geographic regions vary genetically. The intent is to apply this knowledge to revive and sustain wild coho salmon fisheries and improve hatchery production of the species. This information also contributes to British Columbia's coho salmon land-based aquaculture industry, making it more productive and profitable. Working with stakeholders, this team is exploring economic, institutional, regulatory and socialecological opportunities for these genomics tools to optimize their deployment in real-world settings.

Intended outputs and outcomes

- Tools exploring genetic and adaptive variation in coho salmon will be created for use by the coho salmon aquaculture industry.
- The expected result will be an economically viable coho salmon aquaculture industry serving both domestic and export markets, bringing jobs and economic benefits to communities and enhancing Canada's role as a world leader in fisheries and aquaculture genomics.
- The results of the project should also be transferable to other species of Pacific salmon as well as salmonids from other regions of Canada.

Sustaining and securing Canada's honey bees using -omics tools

This project seeks to guard the safety and sustainability of the beekeeping industry in Canada. The project's team will develop genomics and proteomics tools that provide markers to selectively breed 12 economically valuable traits. ("-Omics" technologies refer to the technologies of genomics, transcriptomics, proteomics and metabolomics, etc.) This will enable beekeepers to quickly and cost-effectively breed healthy, disease-resistant, productive bee colonies that are better able to survive harsh Canadian winters. While this will lessen the need to import bees from other regions, it will not eliminate it. The team will also develop an accurate and cost-effective test to detect bees with Africanized genetics ("killer" bees). The team will work with beekeepers and other stakeholders and end users to ensure its tools are implemented and accessible to beekeepers.

Intended outputs and outcomes

- Genomics tools will be created for selective breeding of healthy and productive honey bee colonies as well as for best practices on improving bee health.
- This project will provide measurable economic benefits to Canada, including to beekeepers and the agriculture/agri-food industry, and social benefits to the Canadian public worth \$8 million to \$150 million yearly.

Genomics of abiotic stress resistance in wild and cultivated sunflowers

This project's team is investigating why wild plants are more resistant to environmental stresses than cultivated plants. The team is focusing on the sunflower, a \$20-billion crop that is the only oilseed in the Global Crop Diversity Trust's list of 25 priority food security crops because it is grown widely in developing countries. The project will identify and fully characterize the genetic basis of stress resistance in sunflowers and create resources to enable partners from the public and private sectors to efficiently breed stress-resistant, high-yield cultivars. The team will also develop models to predict likely yields of the new cultivars in different soil and climate conditions across Canada and develop strategies to overcome barriers to research and development caused by international treaties on the use of plant genetic resources. This will ensure maximum use of new plant materials developed from this project for growers in Canada and around the world.

Intended outputs and outcomes

- Genomics tools will be developed to help sunflower breeders identify cultivars that can adapt to climate change.
- The expanded sunflower production made possible in Canada by the new cultivars is expected to yield some \$12 million US annually within five years of the project's 2019 end and up to \$230 million US annually after 10 years. Worldwide, the impact will be substantial, as no other oilseed can maintain the stable yields across as wide a range of environmental conditions as that predicted for the new sunflower cultivars.

Application of genomics to improve disease resilience and sustainability in pork production

Increasing the international competitiveness of the Canadian pork industry and its contributions to global food safety and security is of great importance to this project's team. The team is developing genomics tools that Canadian genetic companies and breeders can use to select pigs that are more genetically resilient due to increased tolerance of, and/or resistance to, multiple diseases (as opposed to being resistant to simply one disease). The tools will also permit pork producers to manage the nutritional

content of pig feed to optimize pig health such that pigs stay healthier, grow more efficiently, have more successful litters and reduce the need for antibiotic use in pig production.

Intended outputs and outcomes

- Genomics tools will be created that help Canadian pork producers with disease pathology and resilience as well as improve antimicrobial-free management.
- The involvement of industry partners in this project means that, within five years of its 2019 end, the rate of genetic improvement and productivity will have an impact on pig production worth more than \$137 million, further improving the international competitiveness of the Canadian pork industry.

Increasing feed efficiency and reducing methane emissions through genomics: A promising new goal for the Canadian dairy group

This team is using genomics-based approaches to select cattle with the genetic traits needed for more efficient feed conversion and lower methane emissions. To date, it has been difficult and expensive to collect the data required for such selection. The latest genomic approaches offer an opportunity to address these problems, and collect and assess the required data to carry out the selection.

Intended outputs and outcomes

- The results of this project will assist dairy farmers and the industry more broadly to develop cattle that will carry these two important traits (feed conversion and lower methane emissions). Farmers will save money as feed is the single largest expense in milk production, while the international competitiveness of Canada's dairy industry will increase.
- The environmental footprint of the dairy industry will also be reduced, in part due to lower methane emissions and because more feed-efficient animals produce less manure waste.
- Broad application of the project's findings will be enhanced by the involvement of several industry organizations and international research partners in the project. This will benefit Canada's dairy industry and contribute to global food security and sustainability.

Application of genomics to innovation in the lentil economy (AGILE)

The goal of AGILE is to provide Canadian farmers with faster access to better lentil varieties that will excel under Canadian growing conditions. The AGILE team will characterize the genetic variability found in an expansive collection of lentils to determine the genetics underlying the ability of lentils to grow well in different global environments. The team, led by Dr. Kirstin Bett and Dr. Albert Vandenberg of the University of Saskatchewan, will then develop breeder-friendly genetic markers that can be used to reduce the impact of genes that cause poor adaptation to Canadian conditions while retaining advantageous genes from these strains. The team will also investigate factors that influence farmers' decisions to adopt lentil or not in their crop rotation and develop a strategy to increase Canadian lentil production in a sustainable way.

Intended outputs and outcomes

- Genomics tools will be developed that allow new varieties of lentils best adapted to the Canadian environment to be bred.
- Outputs from AGILE are expected to result in a three per cent annual rate of increase in lentil productivity, leading to a \$550-million increase in export revenues. This will ensure Canada's continued dominance in research, production and marketing of this important crop.

Reverse vaccinology approach for the prevention of mycobacterial disease in cattle

This team is taking a "reverse vaccinology" approach to preventing infectious diseases in cattle. This approach uses genomic technology to screen large numbers of bacterial proteins simultaneously to identify those with properties that can stimulate a protective immune response in cattle. These proteins then form the basis for developing novel vaccines and immunization strategies. The team will focus on two common cattle diseases: bovine tuberculosis, a debilitating disease that can spread to man and other domestic and wild animals, and Johne's Disease, a gastrointestinal disease. The team will develop and bring to market vaccines for these costly diseases within two years' of the project's 2019 end. The team will also develop companion diagnostics that will differentiate vaccinated animals from infected ones

Intended outputs and outcomes

- The team's work will ultimately increase productivity and profitability for cattle producers and increase public confidence by reducing the use of slaughter or antibiotics to control infections. This work will also enhance Canada's reputation as a major agriculture/agri-food producer.
- The annual financial impact of the vaccines is estimated to be around \$100 million, with international sales of a further \$400 million.

Canadian Triticum Applied Genomics

The Canadian Triticum Applied Genomics team is conducting research to better understand the wheat genome, with the goal of applying this research to develop genetic markers and predictive genetic tests to improve selection efficiency in Canadian wheat breeding programs. The team works with the International Wheat Genome Sequencing Consortium to generate a high quality reference of wheat's chromosome 2B and to drive innovation in wheat breeding by developing genomic strategies to improve the use of untapped genetic variation from related species.

Intended outputs and outcomes

• Tools and strategies will be created for wheat breeders to develop cultivars that are more productive and resistant to disease and pests, and resilient to heat and drought stresses. With these cultivars, wheat farmers can ensure that their product is more productive, profitable and environmentally sustainable.

Toward a sustainable fishery for Nunavummiut

Affordable access to safe, nutritious and culturally relevant food is one of the biggest challenges facing *Nunavummiut* (the people of Nunavut). This lack of affordable, nutritious food is linked to growing health problems, including diabetes and childhood rickets.

Accelerated melting of Arctic sea ice due to climate change is increasing access to arguably the last remaining under-exploited fishery in the northern hemisphere. This increased accessibility – primarily to Arctic char but also to Arctic cod and Northern shrimp – coupled with a developed, sustainable, science-based fishing plan, will offer Nunavut communities employment opportunities and economic benefits as well as greater food security. Understanding the genetic differences among Arctic char, Arctic cod and Northern shrimp populations is key to developing that plan. This project's team, working in collaboration with Nunavut communities, will integrate traditional and local knowledge with leading-edge genomic science and bioinformatics to gain an understanding of the genomes of these fish populations.

- The project will work to strengthen Nunavut fisheries (augmenting sovereignty claims in the Canadian Arctic), bolster employment and economic development in Nunavut communities and ensure the people of Nunavut have access to a healthy food source, thereby improving food security.
- The integration of traditional and local knowledge with leading-edge genomic science and bioinformatics will be used to gain an understanding of the genomes of these fish populations. This will allow the populations' migration, characteristics and adaptation to be monitored and will inform strategies for maintaining genetically diverse and healthy stocks.

SoyaGen: Improving yield and disease resistance in short-season soybean

SoyaGen will probe the genetic code of soybeans to identify DNA markers that control key aspects of plant growth, such as time required to reach maturity and resistance to diseases and pests. Breeders will be able to use these markers to develop improved soybean varieties best suited to Canadian conditions. This project's team will also breed soybean varieties resistant to certain prevailing pests and diseases. As well, they will conduct research focused on maximizing the growth potential of the soybean industry in Canada to accelerate producer adoption of soybeans in western Canada.

Intended outputs and outcomes

- Genomics tools will be created to identify soy varieties best adapted to the Canadian environment.
- Economic benefits of this research have the potential to reach \$278 million annually, based on increasing the yield potential of soybean crops, increasing their resistance against diseases and pests and reducing the use of pesticides.

A Syst-OMICS approach to ensuring food safety and reducing the economic burden of salmonellosis

The Syst-OMICS approach uses whole genome sequencing to identify the specific salmonella strains that cause human disease. With this knowledge, the project's team will develop natural biosolutions to control the presence of salmonella in fruit and vegetables as they are growing in the field. The team will also develop new tests to rapidly and efficiently detect the presence of salmonella on fresh produce before it is sold to consumers, as well as tools to allow public health officials to determine the source of salmonella outbreaks when they occur so that contaminated food can be quickly removed from grocery stores and restaurants.

Intended outputs and outcomes

• The research will reduce the number of people infected with salmonella each year and lower the economic costs of the infection. Salmonella infection is thought to cost the Canadian economy as much as \$1 billion each year in medical costs, absences from work and economic losses to food companies and restaurants.

2012 LSARP Competition - Genomics and Personalized Health: This competition focused on projects with a potential to contribute to a more evidence-based approach to health, improve the cost-effectiveness of the health-care system and ensure that discoveries are translated into patient and population benefits. Projects focused on the application of genomics to tailor patient treatments and therapies in fields as diverse as epilepsy, autism, HIV/AIDS, cancer, cardiovascular disease, rare neurological diseases and stroke, among others.

Projects funded

Autism spectrum disorder: Genomes to outcomes

This work marks Canada's contribution to an ambitious international initiative that aims to sequence and analyze the genomes of 10,000 people with autism spectrum disorder. Genome Canada and CIHR-funded research has already led to some exciting breakthroughs in our understanding of autism spectrum disorder, a complex condition that affects normal brain development, social relationships, communication and behaviour. Among these breakthroughs is the identification of specific DNA anomalies associated with the illness. This project seeks to build on this, with plans to identify the remaining genetic risk factors.

Intended outputs and outcomes

• With a more complete understanding of the genetic elements of autism, doctors will be able to make earlier diagnoses, provide better, more personalized care to patients and reduce the enormous cost autism imposes on the health-care system.

Biomarkers for pediatric glioblastoma through genomics and epigenomics

Genome Canada and CIHR-funded researchers have identified mutations in a particular gene in a significant fraction of children and young adults with this brain tumour. These mutations partly explain why this cancer remains unresponsive to treatments. This project's team is developing new tools that will help health-care providers identify these mutations in brain tumours, allowing children to receive the best treatment strategy. Using next-generation genomics technologies, the team is looking for potential targets for drug treatment.

Intended outputs and outcomes

• These new tools will help health-care providers identify mutations in brain tumours, allowing children to receive personalized and effective treatments.

Clinical implementation and outcomes evaluation of blood-based biomarkers for management of chronic obstructive pulmonary disease

Chronic obstructive pulmonary disease damages the airways inside the lungs, making it difficult to breathe. Patients suffer "lung attacks," characterized by coughing, breathlessness and a dramatic increase in sputum. Lung attacks reduce patient quality of life and cost the Canadian health-care system nearly \$4 billion each year in direct and indirect costs. If caught early enough – or better yet, prevented – lung attacks can be effectively treated with medication. Unfortunately, many of the symptoms of lung attacks can resemble pneumonia, heart attacks or even the flu. This project's team is developing new blood tests that will identify patients at high risk for lung attacks. It will also differentiate these attacks from other conditions.

- Blood tests are being created that have the potential to prevent or treat lung attacks earlier than was previously possible and ensure that patients who need preventative drugs will receive them. This will result in fewer attacks as well as reduced hospitalization and emergency visits.
- Those patients at low risk of an attack will be able to avoid unnecessary drugs and their potential side effects.

Early detection of patients at high risk of esophageal adenocarcinoma

Chronic heartburn can damage the lining of the esophagus, leading to a condition known as "Barrett's esophagus." Patients with Barrett's esophagus have a much higher chance of developing cancer of the esophagus. Until recently, the only way to diagnose Barrett's esophagus was through endoscopy – an uncomfortable and time-consuming procedure. However, a swallowable sponge under development in the United Kingdom allows for quick and painless diagnosis of Barrett's esophagus in a doctor's office. This project's team seeks to supplement this test with genomics technologies, allowing doctors to follow patients over time to identify and treat those progressing to cancer.

Intended outputs and outcomes

• Early detection, treatment and even prevention of this cancer have the potential to save the health-care system over \$300 million a year.

Enhanced CARE for RARE genetic diseases in Canada

Gene mutations cause not only well-recognized rare diseases such as muscular dystrophy and cystic fibrosis but also thousands of other rare disorders. While individually rare, these disorders are collectively common, affecting one to three per cent of the population. It is estimated that as many as half of Canadians with rare disorders are undiagnosed. This project's team is using powerful new gene sequencing technologies to identify the genes implicated in many of these rare diseases.

Intended outputs and outcomes

- This project will provide important new understanding into human disease and other benefits such as discovering ways to avoid invasive procedures, stopping ineffective treatments, developing earlier and better diagnoses, devising more appropriate treatment and predicting the chances that one of these rare diseases could be passed on to offspring.
- Once the disease-causing genes have been identified, researchers will test drugs currently on the market to identify those that might be effective against these rare diseases.

Inflammatory Bowel Diseases Genomic Medicine Consortium: Translating genetic discoveries into a personalized approach to treating inflammatory bowel disease

While there are several drugs available on the market to treat inflammatory bowel diseases, physicians currently are unable to predict which drug would be most effective for a given patient. The Inflammatory Bowel Diseases Genomic Medicine Consortium team will develop tests allowing doctors to match the right drug with the right patient. This will prevent patients from receiving ineffective (and often expensive) medication and allow for quicker improvement to patients' quality of life.

- Once the project is fully implemented, it will save Canada's health-care system more than \$10 million annually by avoiding costly hospitalizations and surgeries.
- The project is creating a system that will become an even greater asset for a large number of new drugs, which are expected to reach the Canadian market in coming years.

Innovative chemogenetic tools to improve outcome in acute myeloid leukemia

Acute myeloid leukemia is a particularly lethal type of cancer among young people. Most die within two years of being diagnosed. At the moment, analyzing cancer cell chromosomes is the best way to determine the prognosis for patients. Unfortunately, about 45 per cent of those tested show no anomalies, leaving doctors with little information to go on. Recent developments in DNA sequencing, however, allow for a more complete analysis of these tumours. This project's team is using personalized DNA from patients to determine how to treat them, based on the specific genetic makeup of their tumours. The team is also developing new models for tracking cancer cells that are left behind after a patient is treated. These cancer stem cells can multiply over time and lead to a relapse.

Intended outputs and outcomes

- This project will lead to better diagnosis and improved outcomes for patients.
- This research could lead to new ways of preventing relapses by providing new insights into the biology of this disease.

PACE -omics: Personalized, accessible, cost-effective applications of -omics technologies

This project is giving policy-makers and investors the tools they need to make the right investment decisions on technology development, regulatory pathways, cost-effectiveness and benefits to the Canadian health-care system. The project's team is developing approaches that properly reflect the views and values of Canadians in making decisions for introducing personalized medicine into cashstrapped health-care systems. Bringing together experts in health economics, health policy, regulation, commerce, law and ethics, they will provide practical decision-making tools and completed analyses that will lead to informed policy-making.

Intended outputs and outcomes

• By helping to establish the ground rules for the development of personalized medicine, this project will make Canada a less risky and more attractive base for developers, thereby supporting economic development in the Canadian life sciences industries.

PEGASUS: Personalized genomics for prenatal aneuploidy screening using maternal blood

Every year in Canada, about 10,000 pregnant women undergo amniocentesis to screen for genetic abnormalities such as Down syndrome. Recently, however, scientists have discovered that fetal DNA present in the mother's blood can be used to test for genetic abnormalities, and this through a simple blood test. The PEGASUS team is comparing different genomics technologies for their effectiveness in successfully detecting genetic abnormalities using the mother's blood." The goal of the study is to implement the most suitable technology into the Canadian health-care system to eventually offer, in the context of standard clinical care, non-invasive prenatal screening to all Canadian women.

• This study will reduce the risk of potential miscarriages caused by the amniocentesis and will render the testing for genetic anomalies less invasive.

Personalized cancer immunotherapy

About half of patients with a hematologic cancer develop resistance to chemotherapy. For these patients, the usual treatment is to transplant bone marrow cells from a healthy donor. This is known as immunotherapy because immune cells from the donor target tumour cells in the recipient. Unfortunately, there are two problems with this treatment: the effectiveness of the transplanted cells varies widely and there is the chance of rejection by the patient. In some cases, the donor cells actually attack the patient – something known as "graft versus host disease." This project's team is developing a genetic test that will predict graft versus host disease.

Intended outputs and outcomes

• This project has the potential to lead to safer use of bone marrow transplants and more effective treatments by targeting the right immune cells to the right tumour cells.

Personalized medicine in the treatment of epilepsy

Every time someone with epilepsy has a seizure, there is a risk of brain damage. This is particularly true for children. Unfortunately, today's anti-epileptic drugs do not work on almost one third of patients. This project's team will identify genes that are associated with epilepsy and are predictive of the response to various anti-epileptic drugs.

Intended outputs and outcomes

• This will result in earlier and more effective care and may potentially prevent cognitive decline in children.

Personalized medicine strategies for molecular diagnostics and targeted therapeutics of cardiovascular diseases

Cardiovascular disease is the leading cause of death and hospitalization in the world. In Canada, 80,000 people died of cardiovascular disease in 2010, accounting for 35 per cent of all deaths in the country. Currently, 1.3 million Canadians suffer from cardiovascular disease. This causes a serious economic burden - the cost is estimated at \$22.2 billion per year, which constitutes the highest direct health-care costs. This project's team is discovering how genes influence drug efficacy and toxicity to provide health professionals with guidance in the selection and dosing of a specific drug.

Intended outputs and outcomes

• This project will improve patient care, reduce harmful side effects and lower health-care costs by reducing the use of ineffective drugs and unnecessary spending.

Personalized risk stratification for prevention and early detection of breast cancer

Currently, mammography is used to screen for breast cancer in women over 50 years of age. While screening younger women could have significant benefits in terms of early detection and intervention, it is simply not economical. What's needed is a way of identifying those who are most at risk, based on a wide variety of factors. This project's team is developing just such a screening program so that women with a high risk of breast cancer will be identified and tested sooner.

Intended outputs and outcomes

• Younger women who are currently missed by age-based screening will have their cancer caught at an earlier stage, leading to better treatment, improved prognosis and lower costs for the health-care system.

Personalized treatment of lymphoid cancer: British Columbia as a model

Lymphoid cancers are special because even when they have spread widely in the body, they can still be cured. Recent research has shown that genomic sequencing can recognize special lymphoid cancers that are often not cured today but which could be treated more effectively using personally designed treatments. This project's research team is applying genetic sequencing to lymphoid cancers – the fourth most common type of cancer. This research will use the province of British Columbia as a pilot project to show how genomic analysis can be harnessed to cost-effectively cure more cancer patients and in a way that can readily be duplicated elsewhere around the world.

Intended outputs and outcomes

• This research could increase the cure rate of several lymphoid cancers by 20 per cent. This translates into more than 40 lives saved annually in British Columbia, upwards of \$2.5 million in savings to the health-care system in that province alone and immeasurable dollars recovered from the ripple effect of disease impacts such as lost work days and family suffering.

Reducing stroke burden with a hospital-ready biomarker test for rapid triage of transient ischemic attacks

Every year, 50,000 Canadians have a stroke, making it the leading cause of disability in the country. However, an equal number of people suffer what are called transient ischemic attacks which, while less serious, can lead to strokes. The problem is that many conditions, including migraines, can present as transient ischemic attacks, leading to expensive neuroimaging testing. What's needed is a quick, inexpensive test that would differentiate transient ischemic attacks from other conditions. This project's team is developing such a test. It will provide results within an hour or so for a fraction of the cost of imaging. With the results of this test, doctors will know whether to keep patients for further care or to send them home.

Intended outputs and outcomes

 Project results will reduce unneeded imaging risks and costs, and prevent transient ischemic attacks from progressing to a full stroke. Averting just 4,000 strokes per year would save \$210 million in direct health-care costs.

The microbiota at the intestinal mucosa-immune interface: A gateway for personalized health

Inflammatory bowel diseases such as Crohn's Disease and ulcerative colitis are incurable, debilitating lifelong diseases that can affect children. Early detection is critical to avoiding complications and

improving quality of life. At the moment, however, there is no single test to determine the presence or type of inflammatory bowel disease and the tests that exist are very uncomfortable for children. This project's team is developing a simple, non-invasive approach to detecting inflammatory bowel disease that will also be more cost-effective. Using cutting-edge technology, the scientists will examine intestinal bacteria to develop better ways of identifying inflammatory bowel disease and determining its severity.

Intended outputs and outcomes

• This project's work could lead to less invasive exploratory care, new treatment options, better quality of life for children and cost savings for the health-care system.

Viral and human genetic predictors of response to HIV therapies

The HIV drug cocktail has transformed AIDS from a fatal disease to a manageable condition. Unfortunately, HIV can become resistant to these drugs, leading to the development of full-blown AIDS in the patient and increasing the chances of further transmission of the virus. This project's team is developing a test for drug resistance personalized to an individual's DNA and the DNA of the virus. The project is also developing real-time surveillance systems for monitoring drug resistance to provide an early warning of geographic or population "hotspots" where resistance rates are highest and the risk of transmission greatest.

Intended outputs and outcomes

 Implementing this pilot project in Vancouver's Downtown Eastside and in Prince George, British Columbia, could avert as many as 173 HIV infections in the first five years. This represents approximately \$65 million in lifetime HIV treatment costs avoided.



Genomics Innovation Network: The goal of this network is to help genomics technology platforms across Canada collaborate and harness their collective power for the advancement of genomics research in Canada, providing the research community with the highest-quality genomics technologies and advice. Each of the Genomics Innovation Network's 10 Nodes provides researchers access to high throughput genomics technologies such as DNA sequencing, proteomics and metabolomics as well as new method and protocol development, data analysis and bioinformatics.

Funding for the Nodes reflects the desire to meet the needs, and ensure the continued success, of projects funded by Genome Canada and other organizations. Funding also fulfils Genome Canada's commitment to further promote technology development and innovation at the Nodes, keeping Canada at the forefront of cutting-edge genomics research.

Outputs and outcomes

• The Genomics Innovation Network increases research capabilities through access to high throughput genomics technologies.

- The network increases the capacity for collaboration among genomics researchers in Canada.
- The network increases the quality and rigour of research by providing the research community with high-quality genomics technologies and advice.
- The network has advanced the development of innovative technologies.
- The network increases Canada's capacity to manage big data.

The 10 Nodes are as follows:

The Proteomics Centre: The Proteomics Centre, located in British Columbia, is a central hub for proteomics research in Canada, providing a "one-stop" shop for an expansive range of high-quality proteomics services.

Sequencing Platform at the BC Cancer Agency Genome Sciences Centre: Since 2001, the sequencing platform at the Michael Smith Genome Sciences Centre at the BC Cancer Agency has been providing large-scale DNA sequencing data and supporting the rapid translation of research outcomes into health-care and other applications.

The Metabolomics Innovation Centre: The Metabolomics Innovation Centre, located in Alberta, is Canada's national metabolomics core facility and technology development centre, providing researchers with world-class resources for studying the thousands of small molecule metabolites that play key roles in biological pathways.

The Centre for Applied Genomics: The Centre for Applied Genomics, located in Ontario, provides genome sequencing and analysis, and other genomics services, to the Canadian and international research communities. Its development of new algorithms and methods for the analysis of whole genome sequence data underpin major international research collaborations.

The Centre for Phenogenomics: Located in Toronto, Ontario, The Centre for Phenogenomics is the largest research facility in Canada designing, producing, and studying more than 250 mouse models each year with specific genetic mutations that allow researchers to learn more about the causes of diseases and develop improved treatments.

Network Biology Collaborative Centre: Ontario's Network Biology Collaborative Centre provides services to Canadian scientists with a focus on functional understanding of the role of genes and gene products in human health and the impact of their alteration on the initiation and progression of human diseases.

Canadian Data Integration Centre: Located in Québec, the Canadian Data Integration Centre offers bioinformatics services to researchers by providing the software and analytic systems for collecting, harmonizing, analyzing and electronically publishing data to assist researchers in understanding the causes, prevention and treatment of human diseases.

McGill University and Génome Québec Innovation Centre: The McGill University and Génome Québec Innovation Centre provides complete DNA and RNA analysis services, using the latest available sequencing and other technologies. The centre also maintains full bioinformatics support for all its sequencing activities, using web-based user interface software.

Center for Advanced Proteomics Analyses: The Center for Advanced Proteomic Analyses, located in Québec, is a multidisciplinary facility that provides state-of-the-art proteomics technology services to researchers in areas such as the development of immunotherapies to fight cancer and the discovery of cellular regulatory mechanisms based on protein interactions and post-translational modifications.

Canadian Centre for Computational Genomics: Located in Québec, the Canadian Centre for Computational Genomics assists researchers in the life sciences in gaining access to bioinformatics and computing resources, helping them realize the potential of genomics research.

National Bioinformatics and Computational Biology Framework: The objective of this initiative is to obtain a clear picture of the current bioinformatics and computational biology landscape in Canada and abroad, and to reach consensus on Canada's strengths, achievements and needs in bioinformatics and computational biology.

Intended outputs and outcomes

- The collaborative and consultative efforts of key players with direct or special interest in the field of bioinformatics and computational biology will lead to the development of a multi-year road map that details the current state of, and future opportunities in, bioinformatics and computational
- This strategy will ensure Canada's competitive position in bioinformatics and computational biology is coordinated, strengthened and sustained.

2015 Bioinformatics and Computational Biology Competition: Following on from the 2012 competition, the objectives of this competition – in partnership with CIHR – are twofold. The first objective is to support the development of next-generation bioinformatics and computational biology tools and methodologies that will be required by the research community to deal with the influx of large amounts of data produced by modern genomics technologies. The second objective is to provide the research community broad access to these new tools.

Intended outputs and outcomes

- This competition will make new tools and methodologies to support genomics research widely available.
- It will become easier to analyze large amounts of data more effectively.
- Maximum benefits will be derived from genomics research.

2012 Bioinformatics and Computational Biology Competition: The objectives of the 2012 competition were the same objectives pursued in the 2015 competition (see the preceding description of the 2015 Bioinformatics and Computational Biology Competition).

Intended outputs and outcomes

- Next-generation bioinformatics and computational biology tools and methodologies required by the research community were developed to deal with the influx of large amounts of data produced by modern genomics technologies and provide broad access to these tools and methodologies.
- Knowledge grew due to the creation of a shared, open-source genetic database amalgamating the work of clinical and research labs across Canada and internationally.
- New research techniques including computing techniques, bioinformatics and genome analytic tools were developed.

Advancing Big Data Science in Genomics Research: This competition was designed to support the establishment of a single national initiative with strong international linkages and the mandate to develop tools and methodologies for integrating multiple -omics data sets generated from other disciplines of biological sciences, as well as phenotypic data collected for different organisms of study. The competition heralded Genome Canada's first partnership with the Canada Foundation for Innovation and the Natural Sciences and Engineering Research Council.

Intended outputs and outcomes

The project funded will develop powerful new computing tools so that
researchers can analyze genetic data from hundreds of cancers to learn more
about how cancers develop and which treatments work best. The powerful new
data-mining tools are expected to be available in 2015-16 for beta testing by
selected cancer genomics and privacy researchers. The facility is to be opened to
the broader research community in 2016.

The project reports:

- nine publications accepted,
- one publication in review,
- · two articles in preparation, and
- 19 presentations at national or international levels.

2015 Disruptive Innovation in Genomics Competition: The key objective of this competition was to support the development of disruptive innovation in the field of genomics, defined as a new genomics-based technology or the application of an existing technology that is transformative because it has the potential to either displace an existing technology, disrupt an existing market or create a new market.

Intended outputs and outcomes

• It is anticipated that disruptive innovations will enable the rapid acceleration of genomics research and will mark a significant leap forward for the genetic revolution – for example, enabling the field of predictive and personalized medicine. New disruptive innovations may decrease the cost of research and/or increase the efficiency and quality of laboratory work.

TRANSLATE DISCOVERIES INTO APPLICATIONS TO MAXIMIZE IMPACT **ACROSS ALL SECTORS**

6 Invest in partnerships between academia and users, in particular industry, to support the application of genomics research

GAPP: This Genome Canada program was designed to increase collaboration between genomics scientists and users of genomics research, as well as to stimulate investment from private and public partners to fund projects that address real-world challenges and opportunities in the field of genomics. Through GAPP, we are connecting genomic academic researchers with users in industry and public sector organizations. Since its launch in 2013, the program has experienced phenomenal success in terms of participation across sectors. Twenty-five projects are currently in play with users focusing on applications as diverse as novel therapeutics, greener automobile manufacturing, improved feed for fish, poultry and swine, enhanced cheese quality and personalized diagnostic tools for lung transplantation and other diseases. It is clear that Canadian sectors are primed to integrate genomics to drive innovation, foster sustainable practices and power the growth of their businesses. Further, through a partnership with Mitacs, GAPP projects are in a position to train the next generation of entrepreneurs who will know how to advance genomics in Canadian industries of the future. (Mitacs is a non-profit, national research organization that manages and funds research and training programs for undergraduate and graduate students as well as postdoctoral fellows in partnership with universities, industry and government in Canada).

Intended outputs and outcomes

- GAPP will increase the engagement of user partners.
- GAPP will boost the number of research partnerships between academia and the private sector to stimulate Canadian innovation.
- It will increase the socio-economic value of genomics research by promoting the application of research results.
- It will boost the level of investment by others, in particular industry.
- It will result in more prototypes or early stage products, tools or processes being developed and moved closer to market or application.
- It will lead to sector leaders having greater recognition of the importance of genomics to their sector.
- It will lead to greater numbers of new receptors/end users being involved.
- It will lead to more genomics research being embraced in policy and practice.

The following are examples of some GAPP-related outputs.

- Xagenic and Dr. Shana Kelley (University of Toronto) This project has had three significant outcomes:
 - follow-on financing of \$40.5 million,
 - an award as Life Sciences Ontario Emerging Life Sciences Company of the Year (2015), and
 - a new partnership agreement for microchip development with a Canadian-based company to further advance the deliverables of the GAPP project.
- · Vineland Research and Innovation Centre and Dr. Keiko Yoshioka (University of **Toronto**) – This project has developed a partnership with a European seed company to generate seed lines that will be used in the GAPP project.

- EWOS Canada and Dr. Matthew Rise (Memorial University) This project was acquired by Cargill for \$1.5 billion, strengthening their focus on farm-raised fish and the need for tailored feed, the focus of the GAPP project.
- LifeLabs and Dr. Suzanne Kamel-Reid (Princess Margaret Cancer Centre) This project led to the opening of a genetic testing facility for Canadians. Testing from the GAPP project will be integrated into the facility.
- MRM Proteomics and Dr. Christoph Borchers (University of Victoria) This partnership has commercialized its first product to emerge from the GAPP project. It has also secured a distribution deal with Cambridge Isotope Laboratories and a co-marketing agreement with Agilent.
- Arcadia Biosciences and Dr. Randall Weselake (University of Alberta) This project has
 completed an initial public offering, raising \$65.6 million to provide further funding and validation
 on the development of advantageous agricultural traits, the focus of the GAPP project.



Entrepreneurship Education in Genomics Program: This program sought to increase entrepreneurial education (skills and training) among genomics researchers and accelerate translation.

Outputs and outcomes

- Scientists became aware that intra/entrepreneurship is one way for them to see their innovation reach the market.
- Graduate students learned that entrepreneurship is one way to create their own employment.
- Project leaders realized that they can increase lab funding through contact research organizations and industry partnerships.
- The number of biotechnology scientists with business and commercialization skills grew.
- More networking opportunities between expert faculty and eminent experts and Canadian scientists arose.

8 Inform policies and practices related to genomics research and its applications according to societal considerations

2012 LSARP Competition – Genomics and Personalized Health GE³**LS Third Modality**: In addition to existing "integrated GE³LS" research components that are conducted within genomics projects, and large-scale and stand-alone GE³LS research projects, Genome Canada has introduced a model of concurrent research that synthesizes and leverages the efforts of research projects within competitions.

An allocation of \$1 million has been awarded to a genomics and personalized health GE³LS network that will assist the GE³LS research undertaken by the projects funded in the 2012 LSARP Competition to generate synergies and efficiencies, share expertise and further advance common goals toward translating research results into practical applications in health care. A network application entitled "GE³LS Network in Genomics and Personalized Health" was approved for funding.

Intended outputs and outcomes

- Best practices will be shared.
- Future collaborative research endeavours will be improved and primed.
- The progress to market of genomics and personalized health technologies will be accelerated.
- The impact of the genomics and personalized health investment will be maximized.

Genome Canada and the Social Sciences and Humanities Research Council Joint Initiative on Societal Implications of Disruptive Innovation in Genomics: The objective of this initiative is to support social science and humanities research and related activities that will enrich the understanding of the societal implications of genomic innovations characterized as "disruptive."

Intended outputs and outcomes

- The number of researchers in social sciences and humanities interested in genomics will rise.
- There will be more multidisciplinary and multi-sectoral research and connection activities.
- Knowledge that may better facilitate the translation of research into application will be produced.
- Knowledge of the societal implications and understanding of disruptive technologies will increase.

Genomics, Public Policy and Society Series: The Genomics, Public Policy and Society series is intended to broker a dialogue between federal policy-makers and researchers on issues that arise at the interface of genomics and society. The series is also intended to help foster evidence-based public policy and identify timely and socially relevant research priorities. Two Genomics, Public Policy and Society events were held in 2015: one at Dalhousie University in October 2015 on the theme of genetically modified crops as a tool of agricultural development and one at the Canadian Science Policy Conference in November 2015, in Ottawa, on the theme of antimicrobial resistance.

Intended outputs and outcomes

- The series will help inform the development of evidence-based public policy in genomics.
- It will identify timely and socially relevant research and policy priorities in genomics.



Grant Management for 2015-16

The federal government, through Innovation, Science and Economic Development Canada, has committed \$1.2 billion in funding to Genome Canada since 2000-01. All funding is provided through funding agreements between Genome Canada and Innovation, Science and Economic Development Canada. Genome Canada and the Genome Centres raise co-funding from others, including the public, not-for-profit and private sectors.

INVESTMENT AND MANAGEMENT OF FUNDS

The audit and investment committee supports Genome Canada's board of directors in fulfilling its fiduciary responsibilities with respect to the management of funds. The committee meets quarterly and reports to the board on the outcome of its deliberations.

The committee is responsible for:

- overseeing the investment and management of funds received from the Government
 of Canada according to a board-approved investment policy that outlines guidelines,
 standards and procedures for the prudent investment and management of funds, and
- overseeing Genome Canada's policies, processes and activities in the areas of accounting and internal controls, risk management, auditing and financial reporting.

The board's programs committee brings further oversight to the management of funds by ensuring research funding and activities are aligned with Genome Canada's strategic priorities. The committee provides advice to the board of directors on research programs and projects, research partnerships and collaborations, competitions and program evaluation.

SOURCE AND USE OF FUNDS

Genome Canada currently manages funds arising from the following five funding agreements.

TABLE 1: GENOME CANADA FUNDING AGREEMENTS WITH INNOVATION, SCIENCE AND ECONOMIC DEVELOPMENT CANADA

FUNDING AGREEMENT	COMPETITIONS AND PROJECTS FUNDED
2008 (\$140 million)	 Competition in applied genomics research in bioproducts and crops. Two research projects through the Cancer Stem Cell Consortium and the International Barcode of Life project. Support for the science and technology innovation centres (now the Genomics Innovation Network), the operations of six regional Genome Centres and Genome Canada through to 2012-13.
2010 (\$75 million)	 Competition in forestry and the environment. Multi-sector competition. Competition for science and technology innovation centre operations support.

	Competition in applied genomics research in personalized health.				
	• Funding of Phase III of the Structural Genomics Consortium (SGC) and continued funding for the International Barcode of Life project.				
2012 (\$65 million)	• Funding for the Public Population Project in Genomics.				
(\$05 million)	Competition in the area of bioinformatics and computational biology.				
	Contribution to the operations of six regional Genome Centres and Genome Canada through to 2013-14.				
	Funding for the Genomic Applications Partnership Program.				
2013 (\$60 million)	• Funding for renewal of science and technology innovation centres for two years.				
(300 million)	• Funding of the SGC and the International Barcode of Life project.				
	Two competitions in large-scale applied genomics research.				
2014 (\$165 million)	• Funding for Genomics Innovation Network operations in 2015-16 and 2016-17 as well as related technology development and collaborative projects.				
	• Funding for national and international partnerships, including the SGC and the International Barcode of Life project.				
	• Contribution to the operations of six regional Genome Centres and Genome Canada through to 2016-17.				

CASH MANAGEMENT

Genome Canada disburses funds on a quarterly basis through the six regional Genome Centres for approved research projects and the Genomics Innovation Network Nodes. On a quarterly basis, each Genome Centre is required to review the expenditures to date and estimate cash requirements for centre operations and for each project and Node that it manages. It then submits a "draw request" to Genome Canada, indicating the cash needs of the centre for the subsequent quarter. The Genome Centres assess the project/Node needs against the approved budget, actual expenditures, scientific progress to date and co-funding received from other sources. Genome Canada then conducts its own thorough review of the draw request submission before releasing funds.

TABLE 2: SUMMARY OF RECEIPTS AND DISBURSEMENTS

Details (in millions of dollars)	Projects funded	Actuals 2000-01 to 2014-15	Forecast 2015-16	Forecast cumulative to 2015-16
RECEIPTS				
Government of Canada		1,015.3	67.4	1,082.7
Investment income		89.3	0.3	89.6
		1,104.6	67.7	1,172.3
PROGRAM AND OPERATING DISBURSEMENTS				
Research projects				
Projects and programs completed in previous years	132	591.7		591.7
2010 Large-Scale Applied Research Project (LSARP): Multi-sector	7	28.7	1.2	29.9
2010 LSARP: Forestry and Environment	9	28.9	1.1	30.0
2012 LSARP: Genomics and Personalized Health	17	22.0	12.6	34.6
2014 LSARP: Genomics and Feeding the Future	11		6.1	6.1
Genomic Applications Partnership Program	17	3.1	8.5	11.6
Entrepreneurship Education in Genomics	2	0.8	0.0	0.8
Bioinformatics and Computational Biology	17	3.1	1.3	4.4
Strategic Initiatives	4		5.5	5.5
Advancing Big Data Science	1		0.5	0.5
Emerging Issues	7	0.8	0.5	1.3
Global Alliance for Genomics and Health	1		0.5	0.5
Structural Genomics Consortium	1	41.8	2.1	43.9
International Barcode of Life	1	15.6	0.6	16.2
Cancer Stem Cell Consortium	3	13.6	3.4	17.0
	230	750.1	43.9	794.0
Genomics Innovation Network Nodes	10	153.3	16.5	169.8
Genome Centres' operations		77.8	4.8	82.6
GENOME CANADA OPERATING EXPENDITURES		94.0	7.5	101.5
Total disbursements	240	1,075.2	72.7	1,147.9
Excess (deficiency) of receipts over disbursements		29.4	(5.0)	24.4
Opening cash balance			29.4	
Closing cash balance		29.4	24.4	



Plans for 2016-17

2016-17 PROJECT AND PROGRAM PLANNING

For the 2016-17 fiscal year, Genome Canada will manage ongoing programs and initiatives funded by the various funding agreements noted in Table 1.

In its 2013 federal budget, the Government of Canada provided Genome Canada with a contribution of \$165 million and a requirement to obtain cofunding of \$280M. In June 2013, Genome Canada's board of directors approved initial allocations of this Government of Canada contribution as follows:

Large-Scale Science - A minimum of \$50 million in funding was allocated to the design and launch of two LSARP competitions. The first LSARP competition (Genomics and Feeding the Future) was launched in June 2014 and 11 projects were approved in June 2015. Genome Canada's investment totalled \$30.8 million with \$5 million from Western Grains and \$54.3 million raised in co-funding. Projects will be actively monitored and managed. Each project has a research oversight committee that is tasked to report to the Genome Centre and Genome Canada on progress being made by the project. The research oversight committee will make recommendations on continued funding and will provide advice and guidance to the research team to help ensure that the project achieves its milestones within the framework of the approved budget.

The second LSARP competition (Natural Resources and the Environment: Sector Challenges – Genomic Solutions) was launched in June 2015 with \$26 million from Genome Canada. Genome Canada will review the full applications to ensure that the objectives of the competition are met. The review committee will make recommendations to Genome Canada's board of directors, who will make the final funding decisions. Funding will be awarded to projects once all applicable conditions are met and Genome Canada funding will begin to flow to the successful applicants in the latter part of the 2015-16 fiscal year.

A total of up to \$10 million in funding was allocated to the International Barcode of Life project and SGC consortia (\$5 million to each consortium) for two years of funding support. This funding ended in 2015-16. The consortium of funders supporting SGC plans to make another round of funding available later in 2016-17.

An allocation of \$1 million was awarded to a genomics and personalized health GE³LS network that will assist the GE3LS research undertaken by the projects funded through the 2012 LSARP Competition. Funds are expected to flow by January 2016. Genome Centre and Genome Canada staff will work with the network to ensure its management structure is well structured and that an oversight committee with external experts is in place, reporting to the Genome Centre.

A total of up to \$10 million in funding was set aside for other strategic research priorities determined by the Genome Canada board of directors in 2014-15. To date, the following funding has been committed:

- ERA-Net for Research Programmes on Rare Diseases (E-Rare-3 project): \$1 million
- CIHR Research Catalyst Network Rare Diseases: \$ 0.2 million
- Canadian Institute for Advanced Research: \$1.25 million
- SGC Interim Funding: \$1.5 million
- Social Sciences and Humanities Research Council Partnership Initiative: \$1 million
- 2015 Bioinformatics and Computational Biology Competition: \$2 million

The review process and funding decisions for the Social Sciences and Humanities Research Council Partnership Initiative will be completed in early 2016-17.

For the 2015 Bioinformatics and Computational Biology Competition, review and funding decisions will be completed in 2016. Projects will have met their conditions and be ready to start by October 2016. The Genome Centres will ensure appropriate monitoring of these projects over the coming years.

Genome Canada will work with the Genome Centres and partner funding organizations to ensure that the initiatives are all monitored and overseen appropriately over the coming year.

Access to Leading-Edge Technologies – A total of up to \$45 million in funding was allocated to support leading-edge technologies that enable Canadian genomics research, including support for the genomics technology innovation centres until fiscal year 2016-17, and to a competition on disruptive innovation.

The Genomics Innovation Network has been operational since April 1, 2015. A contribution has been made to core operating funds and, more recently, to support technology development. By late 2015-16, the Nodes will have the opportunity to apply for collaborative projects, enhancing their ability to work together and demonstrate the power of the latest technologies. These collaborative projects will unfold over 2016-17. The lead Genome Centres will monitor the Nodes regularly. Genome Canada provides oversight of the entire network through an oversight committee of international experts who meet at least once yearly with the Node leaders.

The review of disruptive innovation applications will take place in the last quarter of 2015-16, with funding decisions being made in March 2016. Projects will have met their conditions and be ready to start by July 2016. The Genome Centres will ensure appropriate monitoring of these projects over the coming years.

Translation – In addition to the \$30 million the program was previously allocated from Federal Budget 2012, another \$5.3 million in funding was allocated to the GAPP from Federal Budget 2013. Moreover, up to \$2.5 million in funding initially allocated to entrepreneurial programs was repurposed to GAPP in order to provide more opportunities for Mitacs internships. The plan is to continue to have a GAPP funding round every six months. There are sufficient funds for a GAPP round in early 2016-17. Genome Centres, working with Genome Canada staff and the GAPP core evaluation team, will continue to closely monitor the progress of ongoing projects.

Operations Support – A total of \$19.8 million in funding was allocated to the support of Genome Canada operations and \$14.4 million to the support of operations of the six Genome Centres until fiscal year 2016-17.

Ongoing Projects and Programs – Previously mentioned initiatives that are supported by funds from the 2013 Federal Budget will be either initiated or ongoing in 2016-17. Genome Canada will also continue the necessary fostering of partnerships, administrative oversight and/or monitoring of the following major initiatives, which were launched with funding received from previous federal budgets (2008, 2010, 2011 and 2012). They include the following:

- 2012 LSARP Competition
- 2012 Bioinformatics and Computational Biology Competition
- Advancing Big Data Science in Genomics Research
- Emerging Issue on Porcine Epidemic Diarrhea Virus
- Emerging Issue on the Mount Polley Mine Tailings Dam Breach
- International Rare Diseases Research Consortium
- Cancer Stem Cell Consortium

Five-Year Evaluation (March 2014): Implementation of Recommendations – As per the funding agreements with Innovation, Science and Economic Development Canada, Genome Canada is required to submit an independent third-party evaluation of its activities and projects every five years. The last evaluation was completed in March 2014. The five-year evaluation assessed Genome Canada's relevance and past performance from 2009-10 to 2013-14. The evaluation's findings helped inform management and other stakeholders on progress. It also provided the opportunity to reflect on how Genome Canada is executing Genome Canada Strategic Plan 2012-2017 and how to best implement the organization's strategic direction going forward.

Six recommendations arose from the evaluation that were considered by Genome Canada's management and board of directors in a formal management response. These recommendations, listed as follows, are being implemented as part of annual corporate planning:

- Genome Canada, working with the Genome Centres, should seek out and/or create joint initiatives with a broader range of public and private organizations that aim to achieve similar objectives (e.g., research and development funding programs, partnership programs, business innovation).
- Genome Canada should coordinate with the Genome Centres to develop a communications and engagement plan that identifies strategies for specific audiences/sectors and facilitates the sharing of communications tools and resources.
- Genome Canada should address current information gaps on the effectiveness and weaknesses of integrated GE3LS to confirm its value in facilitating the translation of genomics research and to develop criteria and guidelines to help adjust practices for the integration of GE³LS.
- Genome Canada should further improve working relationships with Genome Centres and collaboratively develop focused and customized funding programs that address the needs of specific sectors, including both large- and small-scale projects, as appropriate.
- Genome Canada should encourage the five science and technology innovation centres to build on their unique strengths (e.g., providing analytical expertise, developing training programs and providing leading-edge technologies at an affordable cost). Genome Canada should also encourage these centres to develop clearer policies and guidelines regarding data sharing and intellectual property, with a view to promoting more open access to data.
- Genome Canada should continue to improve its performance measurement and reporting structures, as well as seek to better integrate its different databases.

PLANNED RECEIPTS AND DISBURSEMENTS 2016-17 **AND SUBSEQUENT YEARS**

The following table provides a preliminary estimate of the receipts and disbursements for 2016-17 and subsequent fiscal years as of December 2015. Genome Canada's operating budget for fiscal year 2016-17 will be presented to the Genome Canada board of directors for approval in March 2016.

TABLE 3: PLANNED RECEIPTS AND EXPENDITURES FOR 2016-17 AND SUBSEQUENT YEARS

Details (in millions of dollars)	Forecast cumulative 2000-01 to 2015-16	Planned 2016-17	Planned subsequent years	Forecast total	Estimated co-funding	Genome Canada and co- funding	%
RECEIPTS							
Government of Canada							
Government of Canada previous agreements	700.0			700.0		700.0	23.5%
Government of Canada March 2008 Agreement	133.8	4.5	1.7	140.0		140.0	4.7%
Government of Canada March 2010 Agreement	75.0			75.0		75.0	2.5%
Government of Canada January 2012 Agreement	57.1	7.9		65.0		65.0	2.2%
Government of Canada January 2013 Agreement	55.0	5.0		60.0		60.0	2.0%
Government of Canada January 2014 Agreement	61.8	49.5	53.7	165.0		165.0	5.5%
Investment income	89.6	0.2	0.1	89.9		89.9	3.0%
Co-funding					1,687.7	1,687.7	56.6%
	1,172.3	67.1	55.5	1,294.9	1,687.7	2,982.6	100.0%
PROGRAM DISBURSEMENT	'S						
Research projects							
Projects and programs completed in previous years	591.7			591.7	695.5	1,287.2	43.2%
2010 Large-Scale Applied Research Project (LSARP): Multi-sector	29.9			29.9	34.8	64.7	2.2%
2010 LSARP: Forestry and Environment	30.0			30.0	31.1	61.1	2.0%
2012 LSARP: Genomics and Personalized Health	34.6	12.3		46.9	107.3	154.2	5.2%
2014 LSARP: Genomics and Feeding the Future	6.1	7.0	19.5	32.6	61.8	94.4	3.2%
2015 LSARP: Natural Resources and the Environment		3.5	22.5	26.0	52.0	78.0	2.6%
Genomic Applications Partnership Program	11.6	13.6	12.5	37.7	75.6	113.3	3.8%

Details (in millions of dollars)	Forecast cumulative 2000-01 to 2015-16	Planned 2016-17	Planned subsequent years	Forecast total	Estimated co-funding	Genome Canada and co- funding	%
Entrepreneurship Education in Genomics	0.8	0.0		0.8	1.7	2.5	0.1%
Bioinformatics and Computational Biology	4.4	2.6		7.0	12.3	19.3	0.6%
Strategic Initiatives	5.5	3.0		8.5	37.1	45.6	1.5%
Advancing Big Data Science	0.5	0.5	1.0	2.0	4.0	6.0	0.2%
Emerging Issues	1.3			1.3	1.4	2.7	0.1%
Global Alliance for Genomics and Health	0.5	0.5		1.0	2.3	3.3	0.1%
Structural Genomics Consortium	43.9			43.9	251.5	295.4	9.9%
International Barcode of Life	16.2			16.2	36.6	52.8	1.8%
Cancer Stem Cell Consortium	17.0	3.6	2.4	23.0	65.7	88.7	3.0%
	794.0	46.6	57.9	898.5	1,470.7	2,369.2	79.5%
Access to leading-edge technologies							
Genomics Innovation Network Nodes	169.8	15.0		184.8	79.7	264.5	8.9%
Disruptive innovation		3.0	12.0	15.0	30.0	45.0	1.5%
	169.8	18.0	12.0	199.8	109.7	309.5	10.4%
Genome Centres' operations	82.6	4.8		87.4	107.3	194.7	6.5%
GENOME CANADA OPERATING EXPENDITURES	101.5	6.7		108.2		108.2	3.6%
Total disbursements	1,147.9	76.1	69.9	1,293.9	1,687.7	2,981.6	100.0%
Excess (deficiency) of receipts over disbursements	24.4	(9.0)	(14.4)	1.0			
Opening cash balance		24.4	15.4				
Closing cash balance	24.4	15.4	1.0	1.0			



Performance, Audit and Evaluation

Genome Canada has a wide array of policies, systems and processes that have been developed over time to address issues of performance, audit and evaluation. The revised *Performance*, *Evaluation*, *Risk*, *Audit Framework* was approved by the board of directors in December 2015.

ANNUAL AUDIT

The annual audit of Genome Canada's financial statements is conducted in accordance with generally accepted Canadian auditing standards. The statements are filed with Innovation, Science and Economic Development Canada by July 31 of each fiscal year. The objective is to express an opinion on whether Genome Canada's financial statements present fairly – in all material respects – the financial position, results of operations and cash flow of the corporation. Upon completion of the audit, the financial statements and a summary of audit findings are presented to the audit and investment committee and then to the board of directors for approval.

RECIPIENT AUDIT

Genome Canada has developed and implemented a recipient audit framework in consultation with the Genome Centres. As part of this exercise, a risk assessment tool was developed to enable the centres to identify projects, including Genomics Innovation Network Nodes that would undergo a detailed compliance audit. This framework was introduced to bring a common approach to recipient audits across Canada and to improve the management control framework within which genomics research is administered.

COMPLIANCE AUDIT

In fiscal year 2011-12, then-named Industry Canada, as a routine practice, initiated a compliance audit of Genome Canada. It was conducted by an independent accounting firm. The stated objective of the audit was to assess Genome Canada's compliance with the requirements of the funding agreement that was in effect in fiscal year 2010-11. The resulting audit report concluded that "...we are of the opinion that GC (Genome Canada) did comply with the requirements of its funding agreement with Industry Canada."

EVALUATION

The terms and conditions of Genome Canada's funding agreements with Innovation, Science and Economic Development Canada specify that every five years, Genome Canada shall carry out an independent third-party evaluation of its grants to eligible projects, including its own activities and projects. The terms and conditions further state that the evaluation will measure overall performance in achieving the objectives identified in the funding agreement. In 2008-09, Genome Canada underwent a full third-party summative evaluation to determine to what extent it had achieved its objectives and mandate. The evaluation concluded that, overall, the rationale for Genome Canada remains strong and important, and that there has been a "transformative" impact of Genome Canada on Canadian genomics research. The second five-year evaluation of Genome Canada was completed in March 2014. The five-

year evaluation assessed Genome Canada's relevance and performance from 2009-10 to 2013-14. The evaluation's findings helped inform management and other stakeholders on progress and how to best implement the organization's strategic direction going forward.

The evaluation demonstrated Genome Canada's value and alignment with the Government of Canada's science and technology strategy, and made it clear that Genome Canada is progressing in the right direction toward achieving its own strategic plan. A number of strengths were highlighted in the report, particularly around the quality of the research that is undertaken. The report noted that Genome Canada has directly contributed to enhancing support and capacity for genomics research through its funding programs and through the development and implementation of a coordinated national strategy. Genome Canada has made a positive contribution to enhancing Canada's international profile and visibility in genomics and to attracting additional investments to support genomic research. The output of peerreviewed papers produced by principal investigators increased significantly with Genome Canada funding. Furthermore, so did the scientific impact (i.e., paper citations, proportion of papers in the 10 per cent most cited category). These positive indictments of the scientific research speak to the rigour of the peer review process that ensures that Genome Canada funds at the highest standard of research.

Notwithstanding the positive advancements made by Genome Canada between 2009 and 2014, there were areas highlighted in the report that warranted further consideration as we forge ahead with delivering on our strategic plan.

Six recommendations arose from the evaluation that were considered by Genome Canada's management and board of directors in terms of contextual considerations, strategic implications and action items to be addressed. As noted in Section IV, the implementation plan for action items that arose from these discussions has been incorporated into this annual corporate planning cycle. While some action items can be easily achieved with distinct projects and short timeframes, others are long-term initiatives embedded into ways of working.



Risks and Challenges

RISK MANAGEMENT

Risk management is integrated into all of Genome Canada's operational, managerial and governance activities. A formal risk management framework is in place and is annually updated and approved by the board of directors. Strategic risks arising from the external operating environment as well as the internal operating environment are assessed on an ongoing basis.

- At the project selection level, risk is managed and mitigated through a process that restricts funding to only those projects judged to have the greatest probability of success from both a scientific and managerial point of view. The viability of each project's success is further mitigated through ongoing monitoring and reviews.
- At the operational level, officers of Genome Canada identify risks and propose strategies for mitigating and reporting (e.g., due diligence routines for review of draw requests and for reviews of funded projects).
- At the managerial level, policies, systems, processes and procedures (administrative, financial, human resource management) are developed, implemented and monitored.
- At the governance level, the board of directors and its committees are aware of their risk management responsibilities and exercise modern governance practices with respect to policy approval and oversight.
- The audit and investment committee is responsible for the monitoring of risk and mitigation strategies and regularly reviews the organization's corporate risk profile.
- The Genome Canada internal working environment culture is one that values honesty, integrity and ethical conduct.

CHALLENGES

Co-funding

To fully implement its five-year strategic plan, Genome Canada proposed a multi-year funding approach as a means of demonstrating to external stakeholders, including the private sector, the federal government's commitment and resolve in supporting genomics and its contribution to Canada's bioeconomy. Under a multi-year funding model, Genome Canada proposed, in 2012, to work toward increasing the leverage ratio from 1:1 to 1:2. Over the past two years, Genome Canada has been able to achieve this ambitious ratio as a result of its greater orientation toward research translation. However, to ensure this momentum of securing co-funding at a ratio of approximately 1:2 continues on a more permanent basis, Genome Canada would require a long-term federal investment.

Year-to-year funding inhibits strategic investment planning and impacts the ability for Genome Canada and the Genome Centres to secure co-funding. A multi-year funding commitment from the Government of Canada at a level substantial enough to allow for the full implementation of the strategic plan would position Genome Canada as a stable and credible partner with industry and the provinces/territories. These co-funding partners require a multi-year planning horizon for the kind of large-scale investments that genomics research generally entails.

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