



# Genomics

DISCOVERY. IMPACT. SUCCESS.



GENOME CANADA STRATEGIC PLAN 2012–2017

## Executive Summary

In our first ten years of existence, three significant activities have been undertaken with a view to cultivating the comparatively young science of genomics in Canada.

The first, with the critical support of the Government of Canada, was the formation of Genome Canada and the regional Genome Centres as a mechanism to induce and support genomics research activities across the country in sectors of strategic importance.

The second was the pursuit of Genome Canada's Mission, which sought to establish a national strategy aimed at fostering genomics developments in terms of scientific output, infrastructure support and research talent.

2

The third was to carefully consider the ethical, environmental, economic, legal and social challenges and opportunities of genomics in all of our activities as a means of influencing research so as to improve the possibilities that scientific discovery would lead to real world benefit.

Collectively, these activities have laid a foundation for a rich, vibrant genomics research community in Canada, and have transformed both the quality and quantity of such research. They have also given rise to the emergence of the Canadian Genomics Enterprise, a highly 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 them to deliver or derive benefits for Canadians.

As we begin our next ten years, we are launching a new strategic plan – bolstered by a new Vision and Mission – that builds upon the progress that has been made and reflects the opportunities and challenges that lay ahead. Going forward, we will play a leadership role in cultivating the Canadian Genomics Enterprise, working in partnership with the regional Genome Centres to bring together the rich mix of research groups, companies, universities, venture capitalists, governments, funding agencies, international organizations, and others who constitute the Enterprise.

We will focus a significant amount of our effort on building or improving ways of translating discoveries into new applications that lead to economic and social benefits as quickly as possible. At the same time, we will continue to fund research and support cutting-edge technology in order to prime this “pipeline” of innovation.

We will target sectors of key economic and strategic importance to Canada: Agriculture, Energy, Environment,

Fisheries, Forestry, Human Health, and Mining. This is an expansion of our previous focus on five sectors. It underscores the pervasiveness of genomics as a driver for the Canadian bio-economy going forward and reflects the progression of new discoveries, applications and benefits of genomics into more sectors.

Genomics is a transformative technology that will play a key role in addressing the most pressing challenges facing society in the 21st century. It is also becoming widely recognized as a critical foundation for numerous applications that will contribute to the emergence of a Canadian bio-economy, one that will ensure the country remains internationally competitive and helps preserve Canadian values and our quality of life in the face of increasingly challenging global issues.

As such, it is vital that all Canadians develop an understanding of genomics and recognize its value. To this end, we will increase our output of high quality information on genomics research, developments and issues so as to garner broad public support. We will also refine or build operating models that increase the ways in which genomics research is shaped by ethical, environmental, economic, legal and social considerations.

To deliver the promise and potential of genomics, we are taking a two-pronged approach to financially support the activities of our plan. First, we are seeking a commitment from the Government of Canada for stable, multi-year funding as a means of demonstrating to our partners, in particular the private sector, the Government's resolve to encourage the growth of its bio-economy. Second, we will multiply the Government's investment substantially by almost doubling the investment from others through the development of strategic partnerships.

We will fulfill the objectives of our new strategic plan by conducting our business within a governance framework that ensures effective oversight of our operations and enhances our transparency and accountability to the public and to the Government of Canada.

The investments made in our first ten years are already leading to real world benefits. Tellingly, they serve as an early indicator of a wave of even greater innovations and impacts that are still to come. The potential of genomics is enormous and we have merely scratched its surface. The time to realize that potential is now. The way forward that we describe in our strategic plan sets out how to do just that.

## Importance to Canada

## Sector Challenge

## Role of Genomics

## Sample Canadian Genomics Projects<sup>1</sup>

### Agriculture

Agriculture, both crops and livestock, are important sectors of Canada's economy and contribute to the well-being of communities across the country. In 2009 the agriculture, agri-food and agri-products sectors accounted for ~\$130 billion or 8.2% of Canada's Gross Domestic Product (GDP), and directly provided one in eight jobs, employing over 2 million Canadians. Canada was the world's fourth largest exporter of food products, with export sales of \$35.2 billion in 2009.<sup>1</sup>

The world's population is forecast to grow to almost 9 billion people by 2030.<sup>2</sup> Feeding this growing population in a sustainable fashion will be a challenge in its own right. Adding to the challenge are reductions in the amount of arable land, which is being lost throughout the world to the forces of urbanization and the impact of climate change. The safety of Canada's food supply is also being challenged by the increase in the level of imports to Canada, which is driven by changing consumer demands from a diversity of markets.<sup>3</sup>

Genomics can provide markers that improve animal health and decrease the costs of livestock production, as well as enhance crop yields, increase nutritional value and improve resistance to pathogens, drought and low temperatures. Genomics can also be used to improve food safety through detection and identification of food-borne pathogens.

- \$189 million (GC and partners) invested in 15 large-scale research projects
  - Crops: canola, wheat, flax, potato, sunflowers, wine grapes
  - Livestock: cattle, swine
- Selection of genetic traits in canola, flax and wheat for adaptation to climate change
- Genomics of grape ripening and yeast fermentation to improve wine quality and vineyard operations
- Development of oilseed crops for bioindustrial products
- Genomic selection techniques to boost genetic improvement in cattle, enhance product traceability and lay the foundation for environmentally sustainable production
- Improving swine health by working in partnership with the swine breeding industry on two of the most common diseases in commercial pig production

### Energy

In 2010 the energy sector accounted for 6.7% of Canada's GDP and Canadian energy exports contributed \$94 billion to the economy.<sup>4</sup> Canada is a world leader in the production and use of energy from renewable resources, with renewable energy sources currently providing about 16% of Canada's total primary energy supply.<sup>5</sup>

Genomics can help develop cleaner ways to produce and use fossil fuels and add high value products such as polymers and lubricants. Genomics can also be used to develop the most appropriate feedstocks for biomass production and optimize the conversion of this biomass to fuel.

- \$42 million (GC and partners) invested in 4 large-scale research projects
- Researchers are providing industry with data that are being used to improve oil sand tailings and make decisions with respect to the environmental sustainability of Alberta's oil sand operations.
- Development of poplar trees that grow faster in a variety of climates across Canada to produce wood that can be more readily converted to biofuel
- Production of fuels from agricultural and forestry wastes
- Sequencing the sunflower, important for its significant potential for biofuel production

### Environment

Canada's environmental market consists of some 8,500 companies with sales of more than \$18.4 billion, including exports worth more than \$1.5 billion each year.<sup>6</sup> These Canadian industries are providing innovative solutions to maintaining health and quality of life and ensuring our ability to sustainably derive benefits from our natural resources.

Genomics can optimize microbial communities that aid in bioremediation. Genomics can also improve our understanding of microbial processes in industrial operations that provide a basis for designing clean, sustainable technologies for commercialization by Canada's environment industry. Genomics can also be applied in environmental monitoring, including monitoring biodiversity and pollution, and using sentinel species in freshwater, marine and terrestrial environments.

- \$119 million (GC and partners) invested in 14 large-scale research projects
- Microbial communities are being developed that can restore contaminated land and water. One community that cleans up sites contaminated with solvents is already commercially available.
- A digital identification system for life is being created through the largest biodiversity initiative ever undertaken, using DNA "barcoding." The information can be used for many purposes such as ecosystem monitoring and controlling agricultural pests and invasive species.
- Genomics tools are being developed to monitor microbial populations to detect changes in the watershed at the source, with the potential to save millions of dollars in water treatment and monitoring as well as ensuring the long-term sustainability of our watersheds and surrounding ecosystems.

### Fisheries

Fish and seafood is Canada's third largest food export, with export revenues of \$3.9 billion in 2010. Canada's five most valuable exports by species in 2010 were lobster, Atlantic salmon, snow/queen crab, shrimp and herring. The Canadian aquaculture industry generates over \$1 billion in GDP and is the fastest growing food production activity in the world. The viability of many coastal communities is directly linked to the health of the fisheries. Approximately 80,000 Canadians make their living directly from fishing and fishing related activities. The aquaculture industry provides another 14,500 jobs.<sup>9</sup>

Canada's fisheries and oceans face a number of challenges including the collapse of key wild fish stocks, competing resource demands, market changes and environmental challenges, such as pollution and climate change.

Genomics can provide markers and other approaches to improve the management of wild fisheries and allow for the protection and enhancement of biodiversity and aquatic fish habitats. For the aquaculture industry, marker assisted selection can be used to establish breeding programs to produce fish with desirable traits, including faster growth rates, disease resistance and thermal tolerance. Genomics can also be used to detect, monitor and minimize the impact of pathogens and thereby improve the health of aquatic animals.

- \$44 million (GC and partners) in 4 large-scale projects
- One Canadian-led international collaboration developed genomic resources for salmonids that are being used to examine responses to environmental factors, pathogens and pollutants, and for broodstock development.
- Another international collaboration is sequencing the salmon genome. The sequence and results from the earlier studies will help improve management of wild fish stocks, breeding selection for the aquaculture industry and programs for food quality, security and traceability.
- A public-private-partnership, established to provide tools and resources to the Atlantic cod aquaculture industry, identified markers for traits related to growth, disease resistance and stress tolerance. Once validated this information will enable marker assisted selection at a commercial scale.

<sup>1</sup>Projects listed as examples are from the research portfolios of both Genome Canada and the Genome Centres. The dollars invested and number of projects funded do not include Genome Centre projects funded independently of Genome Canada.

**Forestry**

More than 600,000 Canadians are directly or indirectly employed by the forest products industry. The forest sector represents some 3% of Canada's GDP, translating to \$75.2 billion in revenues from forestry based goods in 2006. Exports from the sector are worth \$23.6 billion, which translates into a trade surplus of \$14.4 billion—second only to the oil and gas industry.<sup>12</sup> Canadians value forests for biological conservation, recreation, aesthetic and culture and many depend on the industry for their livelihood.

Canada's forests (which make up 10% of the planet's forests) are facing numerous challenges, most notable being climate change, but also rising energy costs, increased human activity and international trade, all of which can lead to changes in insect and disease outbreaks and loss of genetic diversity due to failure to adapt to changing conditions. The result is significant economic, social and ecological costs. For example, from 1998-2007, the mountain pine beetle killed an estimated 17.5 million hectares of pine in BC—almost half of the province's saleable pine, costing tens of billions of dollars.<sup>13</sup>

The genome sciences hold promise for delivering affordable new technologies that will identify genes that confer adaptive traits against pest infestation, disease or environmental changes; help accurately diagnose invading organisms; identify targets for controlling and monitoring invasive pests and diseases; support regulation; and identify traits such as wood quality, and growth. Already management decisions are being influenced by genomics-based evidence.

- \$90 million (GC and partners) in 10 large-scale projects
- Research is focused on identifying genes that confer adaptive traits against pest infestation, disease and environmental changes; genetic features that can help accurately diagnose invading organisms; and markers for wood quality and growth rate:
  - a genetic marker has been identified that plays an important role in the development of Sitka spruce trees that can resist a destructive weevil
  - genomics data are being used to develop new models to monitor the geographical spread of forest pests (such as the mountain pine beetle) and their movement to new species of trees
  - genetic marker technology is being used to identify spruce seedlings that grow faster, produce better wood and are more resistant to insects
  - results from a project focused on predicting the right seedlings for specific climatic conditions will influence reforestation efforts

**Health**

Canada's healthcare expenditure for 2011 is expected to be \$200 billion, or 11.6% of GDP, including spending on hospitals, drugs and physician services. Total health expenditure per capita is estimated to be \$5,800 with Canadians aged 65 or older, consuming nearly 44% of healthcare dollars, despite only totalling 14% of the population.<sup>14</sup>

Canada's health care system is facing challenges including an aging population, the rising incidence of chronic diseases and how best to integrate new technologies that can improve outcomes. By failing to more quickly adopt new technologies, innovative processes and procedures, Canadian health care is becoming less and less efficient, and more and more expensive.<sup>15</sup>

Genomics will allow a paradigm shift from a disease-oriented healthcare system to one that is more personalized, predictive, preventative and cost effective. The future role of genomics lies in: guiding treatment by knowledge of a patient's genome; avoidance of adverse drug reactions using genomic markers; therapeutic intervention and lifestyle modification based on disease risk; stem cells; ability to separate environmental and genomic disease-causing factors; development of new drugs and the repurposing of others to specific sub-populations; rapid real-time sequencing of pathogens to advise on outbreaks; and an understanding of the microbes inhabiting the human body—the microbiome and its correlation with disease.<sup>16, 17</sup>

- \$1.2 billion (GC and partners) in 77 large-scale projects
- In Newfoundland more than 100 lives have been saved by the activation of defibrillators implanted in the chests of individuals carrying the fatal gene responsible for Sudden Cardiac Death—a gene identified by local researchers
- A public-private partnership that supports the discovery of new medicines through open-access research is determining the structure of human proteins of therapeutic relevance to diseases such as cancer, diabetes, and metabolic disorders and placing them in the public domain to be used by industrial and academic scientists alike
- Research is unraveling the complexity of the genetics of autism, opening the way to a DNA test that can be used at birth or even before
- Breast-feeding mothers are now better informed about the use of codeine thanks to research that demonstrated some women have a genetic variant that converts codeine into morphine twice as fast as normal. The US Food and Drug Administration and Health Canada have changed the warning labels on painkillers containing codeine as a result
- A gene associated with common migraines has been identified by a group of scientists from Canada and the UK funded through a public-private partnership
- Identification of markers that differentiate between tumour types in children with the most common form of brain tumours—medulloblastoma—will help doctors determine the most effective interventions for individual patients, limiting severe side effects and the risks of over-treatment.

**Mining**

Mining is a major driver of our country's prosperity. In 2009, the industry contributed \$32 billion to our GDP and employed 306,000 workers in the sectors of mineral extraction, processing and manufacturing. The industry stimulates and supports economic growth both in large urban centres and in remote rural communities, including numerous First Nations communities.<sup>18</sup>

Challenges include managing the complexities of environmental and regulatory requirements, improving the economic viability of mineral extraction and processing, and mitigating environmental impacts from mining activities such as, metal leaching and acid rock drainage.<sup>19</sup>

Genomics can improve the ability to locate, recover and process coal, industrial minerals and metals. The composition of microbial communities can be employed as exploration tools, and microbes used in extraction processes can be enhanced through genomics. Genomics can also assist in cleaning up contaminated sites and identifying micro-organisms and enzymes that can address acid rock drainage and metal leaching.<sup>20</sup>

- Development of an alternate treatment for the bioremediation of mine draining sites by assessing the ability of naturally occurring microbial communities to detoxify contaminated water.

# Our Strategic Plan At A Glance

## GLOBAL CHALLENGES

Human Health, Environmental Sustainability, Food Safety and Security, Clean Energy

**VISION** Harness the transformative power of genomics to deliver benefits to Canadians.

## MISSION

To lead the Canadian Genomics Enterprise by:

- 1 Connecting ideas and people across public and private sectors to find new uses and applications for genomics;
- 2 Investing in large-scale science and technology to fuel innovation; and
- 3 Translating discoveries into applications to maximize impact across all sectors.

## SECTORS OF FOCUS



## OBJECTIVES AND STRATEGIES

### 1 Respond to societal needs by generating discoveries and accelerating their translation into applications

- Involve downstream experts and end-users in priority setting and program design
- Coordinate the development of programs to support the end-to-end integration of research and its application
- Develop innovative models of public-private partnerships
- Foster an entrepreneurial spirit in the scientific community
- Support internationally competitive large-scale science
- Provide leading-edge technologies to Canadian scientists

### 2 Attract greater investment in genomics research from a broad range of stakeholders, in particular the private sector

- Establish strategic partnerships
- Create programs focused on regional priorities

### 3 Enhance the impact of genomics by transforming knowledge of the ethical, environmental, economic, legal and social challenges and opportunities into sound policies and practices

- Develop innovative models of collaborative research
- Shape the innovation continuum
- Enhance accountability through engagement

### 4 Enhance the recognition of the value of genomics by increasing stakeholder appreciation of genome science, its applications and its implications

- Build a world class communications infrastructure using advanced models, tools and methodologies
- Forge linkages with and among other members of the Genomics Enterprise
- Partner with organizations pursuing similar innovation goals, especially in key sectors
- Communicate the advantages and impacts of genomics research and related activities

## OUTCOMES

- 1 Increased breadth and depth of genomics knowledge in economic sectors important to Canada.
- 2 Applications that have positive impacts on policies, regulations, economic development and the quality of life.
- 3 Increased investment in genomics research by a broad range of stake-holders, in particular the private sector.
- 4 Stronger role and influence of ethical, environmental, economic, legal and social aspects in shaping genomics research and its outcomes.
- 5 Increased stakeholder appreciation of the potential of genomics and its impact on society.