

# Genomics

DISCOVERY. IMPACT. SUCCESS.



GenomeCanada

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.

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>

Diminishing supplies of fossil fuels—a finite resource, the impact on climate change of burning fossil fuels and the need to find cleaner ways to use these energy sources and develop renewable sources of energy are drivers in the development of clean energy. Canada now has a mandate for an average of 5% renewable fuel content in Canadian gasoline and a proposed mandate for an average of 2% renewable content in diesel fuel and heating oil.<sup>6</sup> If these goals are to be met using biofuels made in Canada domestic production of ethanol and biodiesel will need to be increased by 9% and 450%, respectively.<sup>7</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>8</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.

Canada's environment, like that in much of the world, is under stress. Climate change is leading to increased air and ocean temperatures, widespread melting of snow and ice and rising sea levels. Air quality can affect human health and the health of the environment. Water, which is more plentiful in Canada than in almost any other country, is coming under stress due to the disposal of human and animal wastes and chemical substances.

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.

These factors compounded by the challenge of feeding a growing world population with an increased appetite for fish are placing significant pressures on the industry to develop new approaches to managing wild fisheries and practicing aquaculture.<sup>10, 11</sup>

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.

## Importance to Canada

## Sector Challenge

## Role of Genomics

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

### 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.

## Genome Canada: Our First Ten Years

Genome Canada is a not-for-profit organization that invests in genomics research in key sectors and fosters networks of expertise in Canada with a view to generating economic and social benefits for Canadians.

We support large-scale genomics research projects, and provide Canadian scientists with access to the most advanced technologies and expertise, through a network of Science and Technology Innovation Centres (STICs). We are completely focused on genomics.

We support genomics research in all the life science sectors of economic and social importance to Canada. Because of this cross-sectoral approach, each sector benefits from knowledge gained through developments in all other sectors.

We work as a cooperative and collaborative network with six regional Genome Centres - Genome British Columbia, Genome Alberta, Genome Prairie, Ontario Genomics Institute, Genome Quebec and Genome Atlantic, combining national leadership with the ability to respond to regional and local needs and priorities. Not surprisingly, this has resulted in regional expertise allowing research results to be translated to those who can use them most effectively. For instance, livestock, energy and crop improvement projects are located in Alberta, Saskatchewan and Manitoba, aquaculture and wild fisheries activities are in the coastal regions, forestry is in western Canada and Quebec, and human health research is prominent in Atlantic Canada, Ontario, Quebec and British Columbia.

With the financial support of the Canadian government for over a decade (totaling \$915 million), and co-funding from provinces, industry, national and international

### Genome Canada by the numbers:

- \$2 billion invested, with more than half secured from partners
- 155 large scale research projects across the life science sectors
- five world-class S&T Innovation Centres
- more than 200 "prepared minds" — project leaders who have developed the skills needed to manage large, complex multidisciplinary science and translate knowledge into application
- more than 4,500 research publications; Canada ranks fifth in the world in terms of scientific impact,<sup>21</sup> and fourth in the world in research related to science and society<sup>22</sup>
- more than 20 companies created
- more than 10,000 highly skilled FTEs employed
- more than 350 patent applicants and patent awards, and 24 license agreements; Canada ranks first in the multi-criteria ranking for intellectual property in genomics in 2005–2007<sup>23</sup>

## The Genome Canada Advantage:

- singular focus on genomics, a technology that cuts across all life science sectors of economic and social importance to Canada
- investment in large-scale projects, essential to address the scale and scope of the challenges being tackled by genomics
- provision of the most advanced technologies and expertise by supporting S&T Innovation Centres and technology development programs
- cross-sectoral approach, creating opportunities to tackle complex questions requiring multidisciplinary expertise, ensuring advances in one sector are applied to other sectors
- unique operating model, combining national leadership with the ability to respond to regional and local needs and priorities
- ability to more than double the Federal investment through co-funding agreements with the public and private sectors
- commitment to maximize benefits and minimize risks by considering the ethical, environmental, economic, legal and social challenges and opportunities of genomics research; and
- business-like approach to choosing, monitoring and managing funded projects in order to optimize return on investment.

funding organizations, philanthropists, Canadian institutions and others, Genome Canada and the regional Genome Centres together have invested almost \$2 billion in genomics research, across all provinces in all life science sectors. The federal investment has been further leveraged by almost a quarter of a billion dollars in funding secured by the Genome Centres to support research initiatives within their regions.

Genomics research may delve into a microscopic world, but the scope of the effort is often macro, involving dozens of scientists, large volumes of data and complex technologies. Our operating model is designed specifically to manage such large-scale investments, with its rigorous selection and oversight processes.

There is another interesting aspect to Genome Canada, one that helps focus projects on innovation, application and, ultimately, economic and social benefits. Our projects are influenced by research that examines the ethical, environmental, economic, legal or social aspects of genomics. This work involves key stakeholders – from industry to the general public. One of the main thrusts of this component is to support and accelerate the adoption of new approaches and technologies. In short, we're helping the country accrue benefits from innovations as quickly as possible.

Genome Canada brings together people and groups in academia, industry, government and elsewhere to cultivate projects that deliver value to Canadians. In particular, our work has a translational emphasis that promotes innovations leading to economic and social benefits, enhanced research or industrial capability, technological advancement and improved infrastructure, policy development and public dialogue.

## Canadian Genomics Enterprise

In our first ten years of existence, Genome Canada and the regional Genome Centres have built a robust and vibrant genomics research community in Canada, transforming both the quality and quantity of such research. This has led 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.

Going forward, Genome Canada will play a leadership role in cultivating the Enterprise, working in partnership with the Genome Centres to bring together the rich mix of research groups, companies, universities, venture capitalists, governments, funding agencies, international organizations and others who constitute it. Our over-arching goals will be to support the end-to-end integration of genome science from discovery to application, and enhance translation and entrepreneurship in order to generate the greatest impact on and benefits for Canadians as quickly as possible.

## The Rise of Genomics in the 21st Century

Genomics is a transformative technology that will play a key role in addressing the most pressing challenges facing society in the 21<sup>st</sup> century. It is also becoming widely recognized as a critical foundation for numerous applications that will contribute to the emergence of an internationally-competitive Canadian bio-economy.

According to the Organization for Economic Co-operation and Development (OECD), the shape of the future bio-economy will depend strongly on breakthroughs in fundamental and applied research in the biological sciences, as well as on commercial opportunities and innovations in regulatory and business models. The OECD recognizes genomics as one of the most important platform technologies that will fuel the development of a global bio-economy, placing genomics at the heart of the world's economic development for years to come. In its landmark report—**The Bioeconomy to 2030**—the OECD projects that “biotechnology could contribute to 2.7% (or about US\$1.1 trillion) of the GDP of OECD countries in 2030.”<sup>24</sup>

Reinforcing the OECD projection, the Centre for the Study of Living Standards (CSLS) has estimated that biotechnology could represent up to 3.99% (or about

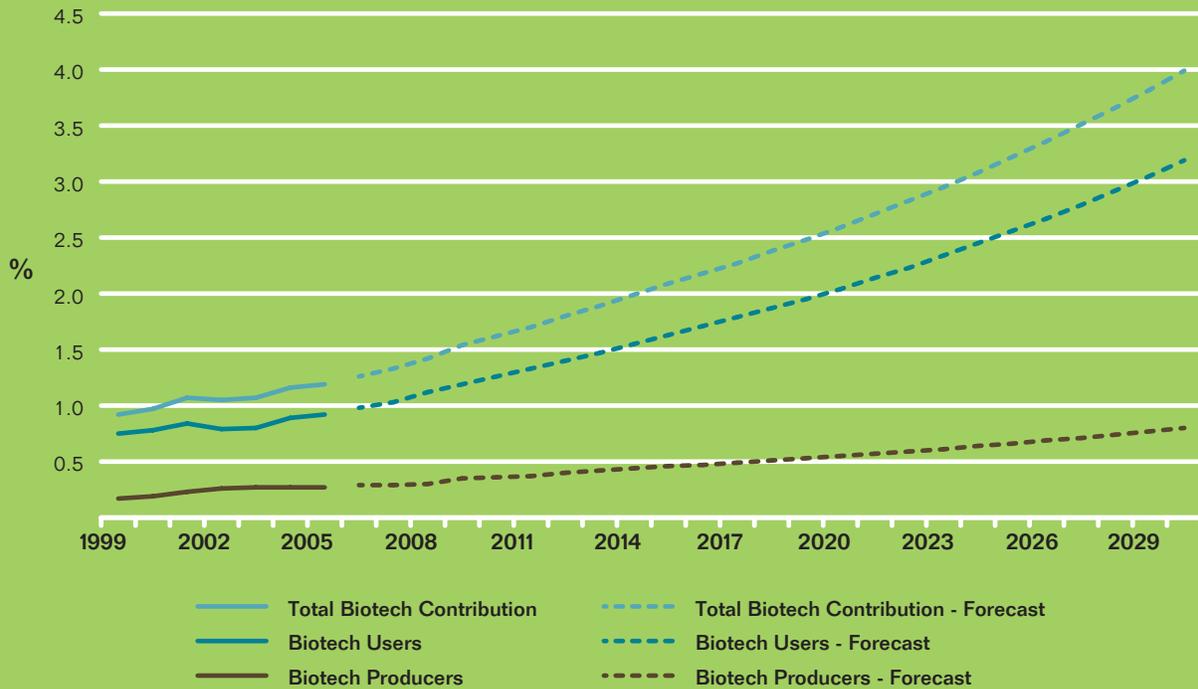
**Energy demand continues to soar, driving a need for alternative and clean sources such as biofuels. “Energy efficiency” will be a key competitive advantage for future economies**

CDN\$144 billion) of Canadian GDP in 2030, driven by factors such as increased demand for food, energy, and healthcare.<sup>25</sup>

We, as a society, face serious and complex global challenges over the coming years. Among them are:

- **Human health:** The economic burden of chronic disease and an ageing population are challenging the sustainability of healthcare systems. New approaches that demonstrate cost effectiveness and are evidence based need to be integrated in a timely manner thus contributing to health maintenance and early diagnosis of disease.
- **Environmental sustainability:** Climate change and other environmental stressors are challenging our ability to sustain our natural resources, including forests, water supplies and air.
- **Food safety and security:** Increasing food production and ensuring the safety of our food supply—through improvements in crops, livestock, wild fisheries and aquaculture industries—are both necessary to feed a growing global population.
- **Clean energy:** Innovation is required to provide new sustainable sources of energy and make more efficient use of existing fossil fuel resources in an environmentally responsible manner.

# Forecasting the Contribution of Biotech GDP as a Share of Total Economy GDP in Canada, 2006–2030



Centre for the Study of Living Standards, 2011.

**A vibrant bio-economy helps fulfill national security and political objectives, ensuring that Canada's voice remains relevant on international issues**

Genome Canada is committed to measures that will help grow the Canadian bio-economy as quickly as possible while addressing key economic and social challenges facing the country and the world at large. We will concentrate our investments in some of the most critical sectors of economic and social importance to Canada—agriculture, energy, the environment, fisheries, forestry, human health and mining. The table starting on page 3 (the foldout) highlights the importance of each sector to Canada's economic prosperity, its challenges, and the potential contribution of genomics to ensuring future growth and

international competitiveness. The table also provides examples of projects funded by Genome Canada and the regional Genome Centres, aimed at addressing these challenges through the use of genomics.

We are already witnessing examples of real-world application of the research we have funded, resulting in economic and social benefits for Canadians, across all of the life science sectors. Tellingly, they serve as an early indicator of a wave of even greater innovations that are still to come that will drive our economy forward. The potential of genomics is enormous and we have merely scratched its surface.

**Government policy aims to develop our diverse energy resources while maintaining a commitment to the environment**

## A Comment about Innovation

There are many challenges still to be addressed by traditional methods of realizing commercial or other gain from scientific discovery. The recognition of the significant nature of these challenges and the need to address them is increasing, particularly within North America. Canada is not immune.

A variety of systemic stressors such as a global leveling of the economic playing field, recognition of Asian countries (especially China) as future drivers of the global economy and innovation, and the rising costs and relatively low success rate of incumbent approaches are contributing to a widespread desire to craft a more successful system.

There appears to be strong interest in moving from a “push” based approach wherein scientific discoveries are used to fuel downstream activities to a “pull” based model wherein science is conducted in the context of a defined challenge. This is not the same as emphasizing one or the other in the term “R&D”. Rather it is growing recognition that there is no point in solving a problem without a need to solve it. Increasingly, downstream

“Innovation is vital to improving Canada’s competitiveness and economy. This, in turn, will create jobs, build a strong economy, support globally competitive businesses and ensure that Canadians benefit in all aspects of their lives.”

— Gary Goodyear, Science and Technology Minister, August 2011

“Science is moving faster than expected.”

“The science is exhilarating but our challenge is how to make the most of it.”

“It’s about risk mitigation. The biggest risk is underestimating the rate of change.”

“Translational research needs to be steered. This is where industry comes in.”

“We are interdependent on each other for innovation. Bring people together.”

“With globalization, it’s going to be harder to be competitive.”

“We don’t invest in Canada. We invest in ideas.”

— Panelist comments from BIO Washington, 2011 and BIOFinance, Toronto, 2011

expertise is required to apply the knowledge gained through science to create something of significant impact. It is about innovation.

Research and innovation serve different purposes. The former is about building knowledge, deriving insight and presenting possibilities. The latter is about bringing to bear aspects beyond the science to generate an economically or socially useful result. However, when we speak of innovation it is often in terms of research, PhDs and other “science” metrics. This is unfortunate and sometimes confusing. Innovation and research are different as illustrated by the following example.

Apple Corporation is broadly recognized as the most innovative company in the U.S. yet ranks approximately 82nd in terms of R&D spending! Apple's strengths lay in the realm of design, marketing and consumer behaviour.

Increasingly, the emphasis is being placed on the translational aspects of research, in terms of both process and content, with a view to accelerating discoveries into applications that benefit society. In turn, this is strengthening interdependence among the scientific, industrial, government and other communities who play a part in the overall process of innovation. It is about creating truly integrated and multidisciplinary teams and platforms.

What does this mean for Genome Canada? We exist and operate at the crossroads of all of this, serving to bridge disparate communities in the public and private sector with a view to driving research, accelerating its translation into innovative uses, and deriving benefits for Canadians from these innovations.

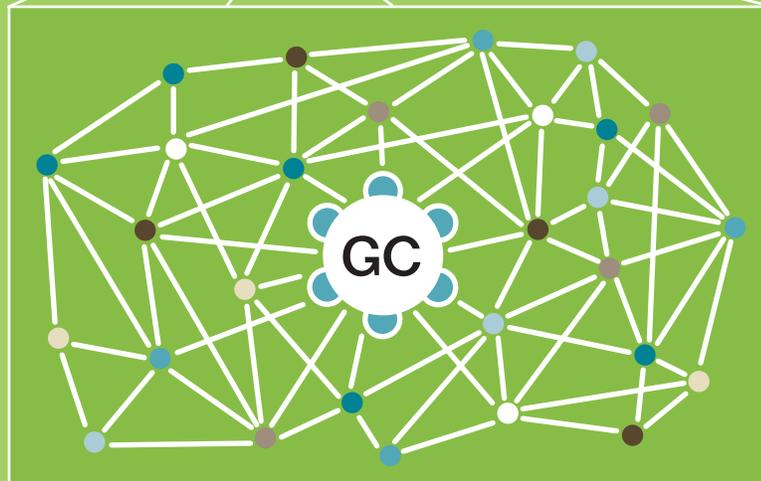
Our emphasis on forming partnerships with industry as well as our focus on all aspects of discovery, translation, and impact, suggests that we are well positioned for impending near- and long-term changes in the research landscape, in Canada and elsewhere. This may prove especially advantageous as we forge more multinational connections in terms of partnerships, research activities and other endeavours.

## The Innovation Continuum



## Canadian Genomics Enterprise

- Genome Canada & Regional Genome Centres
- Venture Capitalists
- Universities
- Companies
- Governments
- Funding Agencies
- International Organizations
- Research Groups



**How Genomics Innovation Happens:** Genome Canada and the regional Genome Centres form the nucleus of a rich, collaborative network of individuals and organizations involved in the discovery, translation and application of genomics knowledge.

The Genomics Enterprise is a complex, expanding network of research groups, companies, universities, venture capitalists, governments, funding

agencies, international organizations and others. Its members are continually strengthening or building linkages in Canada and around the world so as to create genomics innovations that lead to benefits for all Canadians.

Genomics innovation is a continuum of connections, processes and results. Innovation drives and is driven by the constant interplay and intersection of members of the Genomics Enterprise, of new research discoveries, the

ways and means of translating these discoveries into useful applications, and the development of applications engineered to address societal challenges.

As such, Genome Canada and the regional Genome Centres play a central role in fostering all aspects of the Innovation Continuum and in expanding the Genomics Enterprise and interconnecting its members.

# Our Plan for the Next Five Years

Simply, the influence of genomics is accelerating, in virtually all of the ways that matter to Canadians, including:

**Scientific progress and discovery:** Genomics research is providing more insight and understanding of genetic building blocks and pointing the way forward to how they may be used to grow our industries, build our economy and advance our society. This stems from the increasing capability and sophistication of our science infrastructure, i.e., the people and organizations undertaking genomics research and the technology that supports their endeavour.

**Translating science into real world results:** Each application of genomics to solve a real world problem is another step in learning how to derive the greatest benefits from the science. Genomics is leaving the lab and fueling innovation within the rich fabric of public and private sector organizations intent on tackling Canadian challenges in areas such as human health, environmental sustainability, food safety and security, and clean energy.

**Impacting the Canadian way of life:** Canada's bio-economy—with genomics as its foundation—is becoming one of the country's most important strategic assets. At the same time, Canadians are increasingly looking to the biotechnology sector for solutions to the challenges noted previously. In other words, our society is increasingly shaped by the bio-economy.

Genomics holds much promise. Delivering on that promise requires focus, prioritization, direction, and coordination.

It is our intention to foster the advancement of genomics to its fullest potential. To this end, we are launching this strategic plan bolstered by a bold new Vision and Mission appropriate for the next five years and reflective of the enormous promise that genomics offers.

## Our Vision

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

## Our 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.

Going forward, Genome Canada will place greater emphasis on the translational aspects of innovation by applying the knowledge gained from research to grow the Canadian bio-economy and address real-world challenges. In other words, we will become more focused on the endpoint of the research process—the development of applications that lead to economic and social benefits for Canadians. Of course, we will continue to fund research and fuel discovery but even

“The farthest-reaching impacts come from research that builds strong collaborative relationships between industry and science. We give the research community unique insight into the issues and challenges we’re facing and help ensure that, practically, the work done will contribute to the competitiveness of the sector. With its large-scale programs and national scope, Genome Canada is the only organization in the country positioned to create national and international collaborations and leverage industry and other government funding. The two Alberta-led large-scale projects we’re involved in are strong examples of Genome Canada’s capacity to bring together leaders in animal genomics research, industry and provincial funders in a pan-Canadian—in fact, international—effort.”

— Dr. David Chalack, Chair  
Alberta Livestock and Meat Agency

this will become more “purpose-driven,” reflecting our emphasis on the application of research.

This shift in focus will shape virtually all that we do, for example, from setting strategic priorities to influencing the nature of partnerships we form, from how we design programs, to setting the criteria used to select areas for investment.

Accordingly, we have established four essential objectives for the period 2012-2017. In turn, for each objective we have identified a set of key strategies that, in addition to fulfilling the objective, will also help with the expansion and interconnection of the Canadian Genomics Enterprise, with particular emphasis on forging connections to industry.

## Objectives and Strategies

### OBJECTIVE 1

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

To achieve this objective we will:

**Involve downstream experts and end-users in priority setting and program design:** A greater focus on translation and innovation means that more of the research will be driven by identified needs. Such “purpose-driven” research will involve more input and influence from sector and application experts and end-users much earlier in the overall process. To this end, we will create mechanisms to engage the public and private sectors to advise Genome Canada on program design and to guide research teams about the potential impacts and applications of their research from the start of the proposal process.

**Coordinate the development of programs to support the end-to-end integration of research and its application:** Each person or organization comprising the Canadian Genomics Enterprise plays a specific role in the translation of genomics to applications. Genome Canada will work with other members of the Enterprise to build a seamless portfolio of programs that optimizes the entire innovation continuum from research and discovery, to applied research, to development and demonstration, and to translation and commercialization. In short, we will identify what programs are needed and who is best able to provide them.

**Develop innovative models of public-private partnerships:** The private and public sectors are seeking new partnership models to accelerate the pathway from discovery to application and increase the commercialization of innovations. Such partnerships serve as an effective way to pool resources and expertise, reduce duplication of effort and mitigate early stage risks. Increasingly, industry is moving away from “research and development” towards “search and development” due to the burgeoning costs of conducting basic science. In turn, public sector organizations are looking to do more with the science they have undertaken. Genome Canada will explore innovative ways in which to work with industry to build more effective public-private partnerships across all sectors.

**Foster an entrepreneurial spirit in the scientific community:** Perhaps one of the fastest ways to instill an application-based mindset is to cultivate entrepreneurship within Canada's scientific community. To this end, we will expand Genome Canada programs such as our Entrepreneurship Education in Genomics Program to help researchers better understand how to create and capture value from their research and translate their findings into marketable applications, products, technologies, systems and processes.

**Support internationally competitive large-scale science:** Genome Canada will continue to support Canadian researchers in advancing knowledge by investing in large-scale research projects in sectors that are strategically important to Canada, including agriculture, energy, the environment, fisheries, forestry, human health and mining. Our investments will be more directed and focused to ensure that funded research is undertaken with a clear understanding of the end objective. Guided by Genome Canada's Science and Industry Advisory Committee, we will employ sector-focused priority-setting processes involving sector-specific stakeholders and experts, in order to identify the most fruitful areas for investment in each sector and which strategic partnerships to form within and amongst sectors to ensure successful translation.

**Provide leading-edge technologies to Canadian scientists:** Access to the most advanced technologies is crucial to the success of the Canadian Genomics Enterprise. This will be accomplished through a two-pronged approach: enhanced support for the Science and Technology Innovation Centres (STICs) to ensure they remain at the forefront of the latest developments; and the creation of programs focused on advancing technology. Funding mechanisms will be put in place to provide longer term support for the STICs and to allow them to acquire in a timely fashion equipment and technologies newly introduced to the marketplace. A national network of the STICs will be established to allow the centres to work collaboratively, sharing best practices, expertise and innovations. Technology development competitions will be open to both the STICs and individual research laboratories to develop new tools and technologies, essential to advancing genomics research. A specific program focusing on the areas of bioinformatics and computational biology is being established to address the challenges faced as a result of the large quantities of data being generated by the transformative technologies.

## OBJECTIVE 2

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

Over the past decade, research capacity in the genome sciences has grown significantly as a result of prudent investment by the Government of Canada and other stakeholders. This funding helped create a vibrant and robust research community across Canada where one had not previously existed. With Federal support, Canada established itself as a world leader in many aspects of the genome sciences, the country played a central role in several international research undertakings, and new discoveries and innovations were generated in key sectors of the Canadian economy leading to tangible benefits for Canadians.

The Government of Canada has invested \$915 million over the last ten years in genomics research through Genome Canada. In turn, Genome Canada and the regional Genome Centres have leveraged this investment by more than \$1 billion. This additional funding was secured through the development of collaborative relationships and partnerships with private and public sector organizations in Canada and abroad to jointly finance large-scale genomics research projects.

With so much promise, there is burgeoning need for new programs, new partnerships and additional investment. To address this demand, Genome Canada will take a two-pronged approach.

First, we are seeking a commitment from the Federal Government for stable multi-year funding as a means of demonstrating to potential partners, in particular the private sector, the government's resolve to address strategic priorities in their sector and encourage the growth of the Canadian bio-economy (see the Financial Considerations section for full details). Second, we propose to multiply the Government's investment substantially by almost doubling the investment from others through the development of strategic partnerships. To achieve this objective we will:

**Establish strategic partnerships:** Genome Canada will secure new, additional funding for genomics research by working in partnership with the Genome Centres to establish strategic partnerships with national and international organizations representing public and private sectors. In particular, we will seek to expand relations with industry, which together with other private sector investors, currently provides about

15% of co-funding dollars, with a view to doubling industrial support. Our programs will also benefit in other ways from industry support and participation. Such partnerships will bring new perspectives, including business expertise, an entrepreneurial approach and an even stronger focus on applications that deliver real economic and social benefits. We will also focus efforts on further developing our relationships with other private sector organizations and federally supported entities, such as the granting councils (Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council, and the Social Sciences and Humanities Research Council), the Canada Foundation for Innovation, the National Research Council, Sustainable Development Technology Canada, the economic development agencies, and the science-based federal departments (primarily through the Genomics Research and Development Initiative – GRDI), seeking opportunities to work collaboratively in areas within their mandates where genomics can have a significant impact.

**Create programs focused on regional priorities:** The way we operate allows us to show national leadership while responding to local and regional priorities through the regional Genome Centres. Going forward, we will continue to work with the regional Genome Centres and their key stakeholders—such as the provincial governments and regional development agencies—to create funding opportunities focused on the priorities of each region, thereby attracting greater funding from regional partners. We will also encourage and support the Genome Centres in their efforts to raise funding to run programs within their own regions, focused on regional priorities.

### OBJECTIVE 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.

Going forward, genomics is expected to be a foundation for many aspects of the Canadian way of life. As a result, potential impacts must be considered from perspectives that extend beyond science and technology, and include ethical, environmental, economic, legal, and social aspects of genomics research.

Such perspectives can be gained in a variety of ways. One unique aspect of Genome Canada is to support research performed across a range of disciplines in the social sciences and humanities, which spans the

spectrum from basic to applied, from exploratory to evidence-based pilot interventions. Based on our experience, this research can provide a comprehensive and critical understanding of science and technology in relation to other aspects of society and can help move genomics out of the laboratory and into the market, the clinic and society at large. End-users and the Canadian public also can make important contributions to understanding the challenges and opportunities that stand at the intersection of genomics and society.

Genome Canada has developed internationally-recognized expertise to foster such research, including a highly innovative model of integrated research. Without this approach, these many different perspectives would be handled in a fragmented way and advances in genomics would be much less likely to succeed in being transformed into economic and social benefits. At a minimum, such transformations would be slowed considerably.

We are committed to leading the Canadian Genomics Enterprise in transforming knowledge of the ethical, environmental, economic, legal and social challenges and opportunities into sound policies and practices that enhance the impact of genomics.

To achieve this objective we will:

**Develop innovative models of collaborative research:**

Accelerating the transformation of discoveries into applications requires that genomics scientists, social scientists and humanities researchers find the right fit for their collaborations, and engage with others in a coordinated fashion. As a result, we will expand collaborations amongst these groups and other strategic and credible stakeholders within the Genomics Enterprise, and will capitalize on regional strengths as well as national and international expertise across sectors.

**Shape the innovation continuum:** Such collaborations can provide sound evidence for decisions and actions within genomics projects, and can also influence the activities of other stakeholders in the Genomics Enterprise, and beyond. To this end, we will accelerate the creation and spread of information with a view to building broader networks of insight and support, which equipped with sound and actionable knowledge, will become authoritative voices that yield greater influence to enhance the innovation continuum.

**Enhance accountability through engagement:** Support for genomics depends in large measure on whether it responds to the Canadian public's needs, aspirations

and values. This requires that there be a meaningful engagement between the public and the Genomics Enterprise and that such feedback be heard by all levels of decision-makers, as well as researchers. Through established models of consultation, Genome Canada will bring together diverse, interested audiences to explore the ramifications of genomics in society, set shared goals, and actively participate in the Canadian Genomics Enterprise.

#### OBJECTIVE 4

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

The entire genomics endeavour, and Canada's ability to progress and benefit from investments in genomics research and innovation, depends on achieving broad stakeholder recognition, acceptance, interaction and support. Success in achieving this will depend - to a large degree - on highlighting the interplay of genomics activities with other dimensions of Canadian life, and emphasizing the value of these interactions in terms of economic prosperity, scientific and technical advancement, increases in resource capability or capacity, and more.

To this end, Genome Canada is committed to providing stakeholders with high quality information and perspectives required to debate and shape national dialogue about the role, importance and place of genomics in Canadian society. To achieve this objective we will:

**Build a world class communications infrastructure using advanced models, tools and methodologies:** Genome Canada will implement an advanced model of integrated communications planning that evaluates the strategic roles of a variety of communications disciplines and combines them to provide clarity, consistency and maximum impact. In support of the model, Genome Canada will utilize a rich mix of relationship-management tools, distribution methodologies, communications vehicles and performance measurement and evaluation techniques.

**Forge linkages with and among other members of the Genomics Enterprise:** Genome Canada will build upon its successful history of conference and event sponsorships and participation by expanding these efforts. By serving as the "hub" of the Genomics Enterprise, we will be uniquely positioned to bring together viewpoints from a broad range of communities, including research, investment, policy, and industry in whatever format and for whatever purpose that might be required.

**Partner with organizations pursuing similar innovation goals, especially in key sectors:** Beyond the focus of genomics, other organizations share a similar interest in advancing stakeholder understanding of the role and importance of science and innovation. Genome Canada will undertake to form alliances, partnerships, collaborations and other initiatives with such organizations with a view to multiplying the effectiveness of each organization's communications resources and efforts so as to influence more broadly public perception and support.

**Communicate the advantages and impacts of genomics research and related activities:** Genome Canada will undertake a concerted effort to provide synoptic, high quality information about genomics, helping to create context and perspective for research discoveries, and underscoring the value of genomics innovations as well as considering the implications on Canadian progress and prosperity.

## Outcomes

We are committed to our vision of

### Harnessing the transformative power of genomics to deliver benefits to Canadians

and have developed this strategic plan to realize our vision. By 2017, Genome Canada will seek to deliver the following outcomes and will commit to developing specific indicators for each in order to measure and benchmark progress (a sample of performance measures are included below). These indicators will contribute to a larger and more concerted effort by Genome Canada to evaluate the impact and outcomes of its research investments on a continuous and systematic basis.

Outcome	Sample Performance Measures
Increased breadth and depth of genomics knowledge in economic sectors important to Canada.	<ul style="list-style-type: none"> <li>• Genomics related research outputs by sector</li> <li>• Level of recognition by sector leaders of the importance of genomics to their sector</li> <li>• Level of investment by sector</li> </ul>
Applications that have positive impacts on policies, regulations, economic development and the quality of life.	<ul style="list-style-type: none"> <li>• Contributions to the development of technologies, products and devices</li> <li>• Uptake of research into policy and practice</li> </ul>
Increased investment in genomics research by a broad range of stakeholders, in particular the private sector.	<ul style="list-style-type: none"> <li>• Level of funding committed</li> <li>• Number of new funding sources</li> <li>• Level of private sector support</li> </ul>
Stronger role and influence of ethical, environmental, economic, legal and social aspects in shaping genomics research and its outcomes	<ul style="list-style-type: none"> <li>• New models of collaboration involving more stakeholders</li> <li>• More “feedback loops” in the innovation process</li> <li>• International recognition for the quality of Canadian models and approaches</li> </ul>
Increased stakeholder appreciation of the potential of genomics and its impact on society.	<ul style="list-style-type: none"> <li>• Public awareness of genomics and increasing perception of its importance</li> <li>• Stakeholder perception of genomics benefits in key sectors</li> <li>• Recognition as trusted source of high quality information, nationally and internationally</li> </ul>

# Delivering the Plan

---

This strategic plan sets ambitious targets and Genome Canada is strongly positioned to deliver on the plan, due in no small part to our organizational structure and the high calibre of our people.

We operate within a governance framework that reflects our status as a not-for-profit corporation. We employ modern governance practices to ensure effective oversight of the corporation and to enhance our transparency and accountability to the public and to the Government of Canada.

Our **Board of Directors** is a diverse mix of prominent Canadian and international leaders drawn from academic, public, and private sectors. Our Board members are singularly committed to fulfilling Genome Canada's mission and applying their experience and expertise to lead us to success.

As its name suggests, the **Science and Industry Advisory Committee** comprises leading Canadian and international scientists, business people and science administrators who bring to the table diverse experience in the many sectors of strategic importance to Canada.

Genome Canada has a strong **Management Team** experienced in managing significant financial investments, overseeing large-scale research funding programs, and building and managing national and international partnerships and consortia involving the public and private sectors. Our team comprises experienced and respected scientific, financial, government relations, communications, management and administrative expertise.

We are committed to operational and administrative excellence in all aspects of what we do. We apply rigorous standards of accountability to research investments. By combining a world-class scientific peer-review process involving international experts with a financial and managerial due diligence review, we ensure that only the highest calibre projects with the greatest likelihood of success are funded. Once funded, projects are subject to ongoing oversight by the regional Genome Centres, with a formal interim review by Genome Canada. We continue to improve our performance management and evaluation processes, and we manage our general and administrative expenses with economy and efficiency.

The regional **Genome Centres** offer broad experience in developing the linkages and partnerships that enable them to respond to the needs and priorities in their respective regions, raising funds and managing and providing oversight to research projects. Genome Canada and the Genome Centres work closely together to best match and complement regional initiatives and national objectives.

# Appendices

---

## Appendix A: Building the Strategic Plan

Genome Canada is entering its second decade with a solid record of achievement and its original mandate – to develop a national genomics strategy – largely fulfilled.

Now, given an accelerating pace of genomics developments in terms of research, technology, applications and impact, the time is right for a new strategy that more strongly considers current and future realities, including a widespread permeation of genomics solutions into many sectors of strategic and economic importance to the country and the rise of the bio-economy.

Our track record of accomplishments and success, coupled with our new priorities contained in this plan, means Genome Canada is strongly positioned to speed the process of realizing economic and social benefits from genomics research, thus supporting the Government in its new emphasis.

To build our plan, Genome Canada supplemented its own reflection with broad stakeholder consultations, including for example:

- representatives from the six regional Genome Centres,
- those involved in funding genomics research (including other funding agencies, federal and provincial government agencies and departments, and the private sector),
- those who conduct research (including researchers, research institutions, university officials),
- those who use the results of research (including non-governmental organizations, biotechnology and pharmaceutical companies, sector specific end-users and industry associations), and
- members of Genome Canada's international Science & Industry Advisory Committee (SIAC).

In total, more than 160 individuals from more than 70 organizations have been consulted throughout the development of this Strategic Plan. We extend our thanks and gratitude to all who have contributed.

Afexa Life Sciences Inc.  
 Agriculture & Agri-Food Canada  
 Alberta Innovates - Bio Solutions Corporation  
 Association of Canadian Academic Healthcare Organizations  
 Association of Universities and Colleges of Canada  
 Atlantic Canada Opportunities Agency  
 BIOTECCanada  
 British Columbia Cancer Agency  
 British Columbia Centre for Disease Control  
 Canada Foundation for Innovation  
 Canadian Cancer Society  
 Canadian Food Inspection Agency  
 Canadian Institutes of Health Research  
 Caprion Proteomics  
 Centre for Drug Research and Development (BC)  
 Centre Hospitalier de l'Université de Montréal  
 Dalhousie University  
 Economic Development Agency of Canada for the Regions of Quebec  
 Environment Canada  
 Fisheries and Oceans Canada  
 Genome Alberta  
 Genome Atlantic  
 Genome British Columbia  
 Genome Canada's Science & Industry Advisory Committee  
 Genome Prairie  
 Genome Quebec  
 Health Canada  
 Health Charities Coalition of Canada  
 iCAPTURE Centre (BC)  
 Innovation Saskatchewan  
 Manitoba Innovation, Energy and Mines  
 Manitoba Institute of Cell Biology  
 MaRS Innovation  
 Memorial University of Newfoundland  
 Merck Frosst Canada  
 Michael Smith Foundation for Health Research  
 Montréal In Vivo  
 National Research Council  
 National Research Council Plant Biotechnology Institute  
 Natural Resources Canada  
 Natural Sciences and Engineering Research Council  
 NeoVentures Biotechnology  
 Nova Scotia Ministry of Economic and Rural Development  
 Ocean Fisheries Ltd.  
 Ontario Genomics Institute  
 Ontario Ministry of Research and Innovation  
 Pfizer Canada  
 Public Health Agency of Canada  
 Quantum Genetics Canada Inc.  
 Rx&D  
 Samuel Lunenfeld Research Institute  
 Sanofi-Aventis Canada  
 Simon Fraser University  
 Social Sciences and Humanities Research Council  
 Sustainable Development Technology Canada  
 University of Alberta  
 University of British Columbia  
 University of Calgary  
 University of Guelph  
 University of Lethbridge  
 University of Manitoba  
 University of Northern BC  
 University of Saskatchewan  
 University of Toronto  
 University of Victoria  
 University of Waterloo  
 University of Western Ontario  
 Vaccine and Infectious Disease Organization  
 Western Economic Diversification Canada  
 Xenon Pharmaceuticals Inc.

## Appendix B: References

1. Agriculture & Agri-Food Canada, AAFC (2011). An Overview of the Canadian Agriculture and Agri-Food System. Retrieved from <http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1295963199087&lang=eng&src=hp>
2. United Nations (2004). World Population to 2300.
3. Canadian Food Inspection Agency, CFIA (2007). CFIA Renewal Plan 2008-2013. Retrieved from <http://www.inspection.gc.ca/english/hrrh/renpla/renplane.shtml#b>
4. Energy Board of Canada (2010). Canadian Energy Overview 2010 – Energy Briefing Note. Retrieved from <http://www.neb-one.gc.ca/clf-nsi/nrgynfmrtn/nrgyrprt/nrgyvrww/cndnrgyvrww2010/cndnrgyvrww2010-eng.html#s3>
5. Natural Resources Canada (2011). About Renewable Energy. Retrieved from <http://www.nrcan.gc.ca/eneene/renren/aboapren-eng.php>
6. Department of Justice, Canada (2011). Renewal Fuels Regulations. Retrieved from <http://laws-lois.justice.gc.ca/PDF/SOR-2010-189.pdf>
7. KD Communications (Karen Daynard) and Terry Daynard (2011). What are the Effects of Biofuels and Bioproducts on the Environment, Crop and Food Prices and World Hunger? Retrieved from <http://www.gfo.ca/LinkClick.aspx?fileticket=HKfOeU3cHTI%3d&tabid=139>
8. Industry Canada (2010). Environmental Industries: Industry Profile. Retrieved from [http://www.ic.gc.ca/eic/site/ea-ae.nsf/eng/h\\_ea02247.html](http://www.ic.gc.ca/eic/site/ea-ae.nsf/eng/h_ea02247.html)
9. Fisheries and Oceans Canada (2011). Sustainable Fish and Seafood. Retrieved from <http://www.dfo-mpo.gc.ca/fm-gp/sustainable-durable/index-eng.htm>
10. United Nations (2004). World Population to 2300.
11. Fisheries and Oceans Canada (2011). Sustainable Fish and Seafood. Retrieved from <http://www.dfo-mpo.gc.ca/fm-gp/sustainable-durable/index-eng.htm>
12. Forest Products Association of Canada, FPAC (2011). The New Face of the Canadian Forest Industry.
13. British Columbia Government (2011). News Release \$9 million for fight against mountain pine beetle. Retrieved from [http://www2.news.gov.bc.ca/news\\_releases\\_2009-2013/2011JTI0056-000378.htm](http://www2.news.gov.bc.ca/news_releases_2009-2013/2011JTI0056-000378.htm)
14. Canadian Institute for Health Information, CIHI (2011). National Health Expenditure Trends, 1975-2011.
15. Snowdon, A., Shell, J., & Leitch, K.K. (2010). Innovation Takes Leadership: Opportunities & Challenges for Canada's Health Care System. The Ivey Centre for Health Innovation and Leadership. Retrieved from: <http://blogs.ivey.ca/ichil/files/2010/09/White-Paper.pdf>
16. Battelle Technology Partnership Practice (2011). Economic Impact of the Human Genome Project.
17. Organisation for Economic Co-operation and Development, OECD (2009). The Bioeconomy to 2030: Designing a Policy Agenda.
18. The Mining Association of Canada (2011). Retrieved from <http://www.mining.ca/site/index.php/en/>
19. The Mining Association of Canada (2011). Retrieved from <http://www.mining.ca/site/index.php/en/>
20. Genome British Columbia (2007). Towards a Mining Sector Strategy. Retrieved from <http://www.genomebc.ca/index.php?clD=65>
21. Science-Metrix. (2008). Benchmarking of Canadian Genomics – 1996-1997.
22. Science-Metrix. (2008). Benchmarking of Canadian Genomics – 1996-1997.
23. Science-Metrix. (2008). Benchmarking of Canadian Genomics – 1996-1997.
24. Organisation for Economic Co-operation and Development, OECD. (2009). The Bioeconomy to 2030: Designing a Policy Agenda.
25. Centre for the Study of Living Standards, CSLS. (2011). Measuring the Contribution of Modern Biotechnology to the Canadian Economy. Note: The CSLS report identifies the main actors involved in biotechnology activities, dividing them into two groups: biotech producers and biotech users. It then uses data from Statistics Canada's Biotechnology Use and Development Survey (and other sources) to calculate the value added of biotechnology activities using an income-based approach. It excludes value added of both the industries that provide inputs into the biotech sector (backward linked industries) and those that use in a minor way biotechnology products and services (forward linked industries). Multiplier effects are also excluded.



**Genome**Canada

[www.genomecanada.ca](http://www.genomecanada.ca)