BACKGROUNDER

Results of Genome Canada's 2014 Large-Scale Applied Research Project Competition *Genomics and Feeding the Future*

Genome Canada, in partnership with the Western Grains Research Foundation (WGRF), is pleased to announce the 11 successful projects resulting from the 2014 Large-Scale Applied Research Project Competition *Genomics and Feeding the Future*. These projects represent a total investment of $93 million: $30.8 million of federal funding through Genome Canada; $5 million from WGRF towards three of the projects; and, the balance from project co-funders.

BRITISH COLUMBIA

Enhancing production in Coho: Culture, Community, Catch (EPIC4)

Project leaders: William S. Davidson, Simon Fraser University; Louis Bernatchez, Université Laval
Lead Genome Centres: Genome British Columbia, Génome Québec
Total funding: $9.9 million

Fisheries and aquaculture are a $2.5 billion industry in Canada, supporting many thousands of jobs across the country. With 25 per cent of the world's coastline and 16 per cent of the world's fresh water, the importance of fisheries to Canada, and the opportunity that this represents for Canada, cannot be overstated. In BC, for example, seafood is the province's largest agri-food export ($870 million) and contributes 2.2 billion in direct industry revenues annually to the province. Since the 1990s, however, the commercial salmon fishery on the west coast has decreased in value from $263 million to $24 million. The commercial Coho Salmon fishery has been essentially closed since 1999, in part due to declining and endangered populations. Reopening the Coho Salmon fishery, based on recovered and enhanced populations, would bring both economic and social benefits.

EPIC4, under the leadership of Dr. Willie Davidson of Simon Fraser University and Dr. Louis Bernatchez of Université Laval, will develop and use new genomics tools to address challenges facing the safe, secure and sustainable production of Coho Salmon. The interdisciplinary team of natural and social scientists will sequence the Coho Salmon genome, document the genetic diversity of thousands of individuals and determine how Coho Salmon from different geographic regions vary genetically. They will apply their knowledge to revive and sustain the wild Coho Salmon fisheries. This information will also help develop BC's Coho Salmon land-based aquaculture industry to make it more productive and profitable. Working with stakeholders, EPIC4 will explore and understand fully the economic, institutional, regulatory and social-ecological opportunities for these tools to optimize their deployment in real-world settings.

The result will be an economically viable Coho Salmon aquaculture industry serving both domestic and export markets, bringing jobs and economic benefits to communities and enhancing Canada's role as a world leader in fisheries and aquaculture genomics. The results of the project should also be transferable to other species of Pacific salmon as well as salmonids from other regions of Canada.

Sustaining and securing Canada's honey bees using 'omic tools

Project leaders: Leonard Foster, University of British Columbia; Amro Zayed, York University
Lead Genome Centres: Genome British Columbia, Ontario Genomics Institute
Total funding: $7.2 million

Honey bees play a critical role in Canadian agriculture. They produce 75 million pounds of honey each year and are responsible for pollinating many fruits and vegetable crops, nuts and oil seeds like canola. Through these activities, they contribute more than $4.6 billion to the Canadian economy each year.

Given this critical role, the high rate at which bee colonies are dying off is particularly alarming, posing a serious threat to the productivity of Canadian agri-food industries and jeopardizing Canada's food security. Canadian beekeepers have lost more than a quarter of their colonies each winter since 2006-07 with certain provinces experiencing significantly higher death in some years. Replacing these losses by purchasing queen bees from offshore, as beekeepers have been doing, risks importing new diseases or invasive strains of honey bees (such as "killer" bees from the US).

Dr. Leonard Foster of the University of British Columbia and Dr. Amro Zayed from York University are leading a project to guard the safety and sustainability of the beekeeping industry in Canada. The team will develop genomics and proteomics tools that will provide markers to selectively breed 12 economically valuable traits. This will enable beekeepers to quickly and cost-effectively breed healthy, disease-resistant, productive bee colonies that are better able to survive harsh Canadian winters. While this will lessen, it will not eliminate, the need to import bees from other regions, so the team will also develop an accurate and cost-effective test to detect bees with Africanized genetics ("killer" bees). The team will work with beekeepers and other stakeholders and end users to ensure its tools are implemented and accessible to beekeepers by the end of the project. This will provide measurable economic benefits to Canada, including to beekeepers and the agri-food industry and social benefits to the Canadian public. These benefits range in value from $8 million to $150 million per year.

Genomics of abiotic stress resistance in wild and cultivated sunflowers

Project leaders: Loren H. Rieseberg, University of British Columbia; John M. Burke, University of Georgia
Lead Genome Centre: Genome British Columbia
Total funding: $7.9 million

It's not easy being a plant. Drought, flooding, salt and low nutrient levels negatively affect plant growth and lower crop productivity. These environmental stresses have the greatest impact on our highly adapted domesticated crops while their wild plant relatives have evolved mechanisms to help them overcome these challenges. Understanding these mechanisms will enable cultivated crops to be grown in previously unsuitable habitats and in the face of changing climatic conditions, thus feeding a rapidly growing global population. Sunflowers are ideal for this project, as they are limited by environmental stresses but have wild counterparts adapted to a variety of extreme environments.

Dr. Loren H. Rieseberg of the University of British Columbia and John Burke of University of Georgia are leading an international team investigating why wild plants are more resistant to environmental stresses. The team is focusing on the sunflower, a $20 billion crop that is the only oilseed in the Global Crop Diversity Trust's list of 25 priority food security crops because it is grown widely in developing countries. The project will identify and fully characterize the genetic basis of stress resistance in sunflowers and create resources that will enable partners from the public and private sectors to efficiently breed stress-resistant, high-yield cultivars. The team will also develop models to predict likely yields of the new cultivars in different soil and climate conditions across Canada and develop strategies to overcome barriers to R&D caused by international treaties on the use of plant genetic resources thus ensuring the maximum use of new plant materials developed from this project for growers in Canada and around the World.

The expanded sunflower production made possible in Canada by the new cultivars is expected to yield some $12 million USD annually within five years of the project's end and up to $230 million USD annually after ten years. Worldwide, the impact will be substantial, as no other oilseed can maintain the stable yields across as wide a range of environmental conditions as that predicted for the new sunflower cultivars.

ALBERTA

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

Project leaders: Michael Dyck, University of Alberta; John Harding, University of Saskatchewan; Bob Kemp, PigGen Canada Inc.
Lead Genome Centres: Genome Alberta, Genome Prairie
Total funding: $9.8 million

Pork is big business for Canadian producers, both domestically and internationally. In Canada, it is the second-most consumed meat. Globally, Canadian pork is exported to more than 100 countries and it is consumed throughout the world more than any other source of protein. Managing disease in pork populations is one of the most costly and difficult challenges for pork producers. In addition to its economic costs, disease likely contributes to public perceptions of animal products in terms of animal welfare, food safety and antimicrobial resistance. Genomics offers new ways to fight disease in pigs, reducing costs for producers, increasing product quality and improving public perceptions. This will become increasingly important as global demand for animal proteins rises in concert with growing populations.

Dr. Michael Dyck of the University of Alberta, Dr. John Harding of University of Saskatchewan and Dr. Bob Kemp of PigGen Canada Inc. are leading a team that will increase the international competitiveness of the Canadian pork industry and its contributions to global food safety and security. The team is developing genomics tools that Canadian genetic companies and breeders can use to select pigs that are more genetically resilient due to increased tolerance of and/or resistance to multiple diseases (as opposed to simply resistant to one particular disease). The tools will also permit producers to manage the nutritional content of pig feed to optimize pig health such that pigs stay healthier, grow more efficiently and have more successful litters and reduce the need for antibiotic use in pig production.

The involvement of industry partners in this project means that, within five years of its end, the rate of genetic improvement and productivity will have an impact on pig production of more than $137 million, further improving the international competitiveness of the Canadian pork industry.

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

Project leaders: Filippo Miglior, University of Guelph; Paul Stothard, University of Alberta
Lead Genome Centres: Genome Alberta, Ontario Genomics Institute
Total funding: $10.3 million

The Canadian dairy industry adds $16.2 billion to Canadian GDP each year (2011 figures). That figure is forecast to increase as international demand for dairy products grows in the coming years, due to growing middle classes in emerging economies, demand for high-quality milk proteins in developing countries and world population expansion more generally. That figure can also grow (by an estimated $100 million annually) by improving two key traits in dairy cattle: their ability to convert feed into increased milk production and a reduction in their methane emissions (methane being a powerful greenhouse gas).

Dr. Filippo Miglior of the University of Guelph and Dr. Paul Stothard of the University of Alberta are leading a team that will use genomics-based approaches to select for cattle with the genetic traits needed for more efficient feed conversion and lower methane emissions. To date, it has been both difficult and expensive to collect the data required for such selection. The latest genomic approaches offer an opportunity to address these problems and collect and assess the required data to carry out the selection.

The results of this project will assist dairy farmers and the industry more broadly to develop cattle that will carry these two important traits. Farmers will save money (as feed is the single largest expense in milk production), while the international competitiveness of Canada’s dairy industry will increase. The environmental footprint of the dairy industry will also be reduced, in part due to lower methane emissions, but also because more feed efficient animals produce less manure waste. Broad application of the project’s findings will be enhanced by the involvement of several industry organizations and international research partners in the project, not only benefiting Canada’s dairy industry, but also contributing to global food security and sustainability.

PRAIRIE

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

Project leaders: Kirstin Bett and Albert Vandenberg, University of Saskatchewan
Lead Genome Centre: Genome Prairie
Total funding: $7.9 million (includes funding from Western Grains Research Foundation)

Lentils may be tiny, but they are an outsized source of opportunity for Canadian farmers. Canada is the world’s largest producer and exporter of lentils, exporting more than $14 billion worth of lentils since 1997. Lentils are eaten around the world, easy-to-cook, and high in protein and micronutrients, thus contributing to global food security.

Lentils have been a success for Canada, because farmers have access to high-quality and high-yielding lentil varieties that are well-adapted to Canada's climate conditions – a result of a dedicated lentil breeding program in Canada. Breeders, however, have only been able to access a small fraction of the total diversity in existence, which hinders Canadian farmers' ability to meet the growing global demand.

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

Output from AGILE is expected to result in a three per cent annual rate of increase in productivity, leading to a $550 million increase in export revenues, thus ensuring Canada's continued dominance in research, production and marketing of this important crop.

Reverse vaccinology approach for the prevention of mycobacterial disease in cattle

Project leaders: Andrew Potter, VIDO-InterVac, University of Saskatchewan; Robert Hancock, University of British Columbia
Lead Genome Centres: Genome Prairie, Genome British Columbia
Total funding: $7.4 million

This project aims to develop vaccines against two important infectious diseases of cattle, Johne's disease and bovine tuberculosis. Infections are a leading cause of sickness and death in cattle, causing direct economic losses to producers and even more serious losses associated with international trade restrictions (as seen with mad cow disease) and decreased public confidence in food quality. Infectious diseases also pose a risk to human health if they are transferred to people. The most effective way to prevent infectious disease in animals such as cattle is vaccination. Lack of effective vaccines for some diseases contributes to the overuse of antibiotics and to a strategy of slaughtering infected animals, which has come under increasing public scrutiny.

Dr. Andrew Potter of VIDO-InterVac, University of Saskatchewan and Dr. Robert Hancock of the University of British Columbia are leading a team taking a "reverse vaccinology" approach to preventing infectious diseases in cattle. This approach uses genomic technology to screen large numbers of bacterial proteins simultaneously to identify those that have properties that can stimulate a protective immune response in cattle. These proteins then form the basis for developing novel vaccines and immunization strategies. The team will focus on two common cattle diseases, bovine tuberculosis, a debilitating disease that can spread to man and other domestic and wild animals, and Johne's Disease, a gastrointestinal disease, developing and bringing to market vaccines for these costly diseases within two years' of the project's end. The team will also develop companion diagnostics that will differentiate vaccinated from infected animals.

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

Canadian Triticum Applied Genomics (CTAG^2)

Project leaders: Curtis Pozniak, University of Saskatchewan; Andrew Sharpe, National Research Council Canada
Lead Genome Centre: Genome Prairie
Total funding: $8.5 million (includes funding from Western Grains Research Foundation)

Wheat accounts for a staggering 20 per cent of all calories consumed throughout the world. As global population grows, so too does its dependence on wheat. To meet future demands, productivity for wheat needs to increase by 1.6 per cent each year – at the same time as climate change is causing temperature and precipitation changes that challenge established patterns. There is, in addition, a need to ensure that productivity increases are achieved sustainably to ensure the long-term stability of the wheat-growing industry.

In Canada, wheat accounts for more than $4.5 billion in annual sales and, when value-added processing is factored in, adds more than $11 billion each year to the Canadian economy. Dr. Curtis Pozniak of the University of Saskatchewan is leading the CTAG^2 team, with scientists participating from four Canadian research institutions: The National Research Council of Canada, Agriculture and Agri-Food Canada, University of Guelph, and the University of Regina. The emphasis of CTAG^2 is to conduct research to better understand the wheat genome and to apply this research to develop genetic markers and predictive genetic tests to improve selection efficiency in Canadian wheat breeding programs. The CTAG^2 team will work with the International Wheat Genome Sequencing Consortium to generate a high quality reference of chromosome 2B of wheat and drive innovation in wheat breeding by developing genomic strategies to improve utilization of untapped genetic variation from related species. The end result will be the development of tools and strategies for wheat breeders to develop improved cultivars that are more productive and resistant to disease and pests, and resilient to heat and drought stresses. These cultivars will enable wheat farmers to ensure that their product is more productive, profitable and environmentally sustainable.

The project is part of an international collaboration to sequence the entire wheat genome and to characterize genetic variation influencing critical traits targeted by wheat breeders in Canada.

ONTARIO

Towards a Sustainable Fishery for Nunavummiut

Project leaders: Virginia K. Walker, Queen's University; Stephen C. Lougheed, Queen's University; Peter Van Coeverden de Groot, Queen's University; Stephan Schott, Carleton University
Lead Genome Centre: Ontario Genomics Institute
Total funding: $5.6 million

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

Accelerated melting of Arctic sea ice due to climate change is increasing access to arguably the last remaining under-exploited fishery in the Northern Hemisphere. This increased accessibility, primarily to Arctic char, but also to Arctic cod and Northern shrimp, coupled with a developed, sustainable, science-based fishing plan will offer opportunities for employment and economic benefits for Nunavut communities as well as greater food security. It is the Nunavummiut that should be the beneficiaries of these resources, rather than foreign fishing fleets.

Understanding the genetic differences among these fish populations is key to developing that plan. Dr. Virginia K. Walker of Queen's University and colleagues together with the Nunavut communities will integrate traditional and local knowledge with leading-edge genomic science and bioinformatics to gain an understanding of the genomes of these fish populations. This will allow monitoring of their migration, characteristics and adaptation and inform strategies to maintain genetically diverse and healthy stocks. The project will work toward strengthening Nunavut fisheries, augment sovereignty claims in the Canadian Arctic, increase employment and economic development opportunities, ensure access to a healthy food source, and improve food security for the people of Nunavut.

QUEBEC

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

Project leaders: François Belzile, Université Laval; Richard Bélanger, Université Laval
Lead Genome Centre: Genome Québec
Total funding: $8.3 million (includes funding from Western Grains Research Foundation)

Soybean is a promising crop for Canadian farmers, already the third-most important field crop in Canada and generating more than $2.5 billion annually. Its seeds are a valuable source of protein and oil for both human and animal consumption. It does not need chemical fertilizer to provide it with nitrogen as it naturally extracts it from the air with the help of bacteria in the soil, making it environmentally friendly. However, there are challenges involved in developing high-yielding soybean varieties suited to Canadian conditions: First, they need to reach maturity quickly, within the short Canadian summer; second, they need to be made more resistant to pests and diseases, to prevent losses in yield or require the use of pesticides; and third, because it is a novel crop in many regions of Canada, there are impediments to its adoption by farmers that need to be addressed.

Dr. François Belzile and Dr. Richard Bélanger of Université Laval, are leading a team that will probe deeply into the genetic code of soybeans to identify DNA markers that control key aspects of plant growth such as time to maturity and resistance to diseases and pests. Breeders will be able to use these markers to develop improved soybean varieties best suited to Canadian conditions. The team will also breed soybean varieties resistant to certain prevailing pests and diseases. As well, they will conduct research focused on maximizing the growth potential of the soybean industry in Canada to accelerate producer adoption of soybeans in western Canada. Economic benefits of this research have the potential to reach $278 million annually, based on increasing the yield potential of soybean crops, increasing their resistance against diseases and pests and reducing the use of pesticides.

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

Project Leaders: Lawrence Goodridge, McGill University; Roger C. Levesque, Institute for Integrative Systems Biology (IBIS), Université Laval
Lead Genome Centre: Génome Québec
Total Funding: $9.8 million

It used to be that poultry was the usual suspect in cases of *Salmonella* poisoning. Today, however, most outbreaks of the illness come from fruit and vegetables, which become infected from the soil they grow in when that soil is polluted by animal waste or non-potable water. There currently is no method of reducing the growth of *Salmonella* on such produce.

Each year, *Salmonella* infects some 88,000 people in Canada who consume contaminated food. And while many people suffer no ill effects, or a mild case of abdominal cramps, fever or diarrhea, others experience more serious infections, which can result in dehydration or infection travelling beyond the intestines, requiring medical attention and resulting in disability or even death. *Salmonella* infection is thought to cost the Canadian economy as much as $1 billion each year in medical costs, absences from work and economic losses to food companies and restaurants.

Dr. Lawrence Goodridge of McGill University and Roger C. Levesque from IBIS, Université Laval, are leading a team that is using whole genome sequencing to identify the specific *Salmonella s*trains that cause human disease. With this knowledge, the team will develop natural biosolutions to control the presence of *Salmonella* in fruit and vegetables as they are growing in the field. The team will also develop new tests to rapidly and efficiently detect the presence of *Salmonella* on fresh produce before it is sold to consumers, as well as tools to allow public health officials to determine the source of *Salmonella* outbreaks when they occur, so that contaminated food can be quickly removed from grocery stores and restaurants. Their work will reduce the number of people infected with *Salmonella* each year, as well as the economic costs of the infection.