



# Aquatic and Terrestrial Animal Genomics

Leading and Enhancing Canadian Animal Health and Productivity to 2025

**A Position Paper Submitted to Genome Canada  
July 4, 2008**

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## Executive Summary

**Investment is made for future opportunity and by not preserving a questionable status quo. The knowledge intensive bio-economy is real, is here today, and will create potentially huge new value for agriculture in the future.**

*Canadian Agri-Food Policy Institute 2007* 

**The theme: The Aquatic and Terrestrial Animal Genomics (ATAG)** theme harnesses the internationally competitive Canadian agriculture and aquaculture industries, the nation's abundant natural resources of land and water and the federally and provincially supported research initiatives that have made Canada a natural global bio-resources leader. Animal production and processing employs one in eight Canadians, a \$34.5B business. The research opportunity presented by this theme will enable improvements in animal production, human health and industry. This will create more than \$8B annually in new wealth for Canadians by 2025. Canada must continue to be a leader in international food security through improved utilization of the nation's natural assets at a time when food supplies are considered inadequate to meet global needs. Globally, 835 million people are malnourished and the demand for protein sets new records annually. The research developed will add stability, sustainability, profitability and improve animal welfare for the nation's livestock and aquaculture industries, and provide healthier food for Canadians.

**The 'omics:** Genomics technologies provide tools to improve animal production systems through marker assisted selection (MAS) to develop useful, sometimes novel, traits to monitor the environment, to improve animal welfare, and to determine impacts of agriculture and aquaculture on our natural resources including wild populations. The ATAG theme deliverables of improved tools of production and protection focuses on strategic development of existing made-in-Canada 'omics solutions and novel developments to promote sustainable growth of animal agriculture and aquaculture. It will use these resources to assess, monitor and safeguard wild animal populations and their environments, and build opportunities to secure Canada's place as a leader in animal health and welfare.

**Canada's advantage:** Canada has 25% of the world's coastline and 16% of the world's fresh water, but only produces 0.4% of the planet's aquaculture, yet is the 5<sup>th</sup> largest seafood exporter, by value. Canada is the world's 3<sup>rd</sup> largest exporter of feed grain and our arable land per person is nearly double that of competing nations; thus, we have a vast capacity to support growth in animal production. Canada has unparalleled animal health systems and identification protocols, a unique advantage in large-scale aquaculture and terrestrial animal production. Canada has strong investment in research infrastructure and early development of genomics tools and the ATAG theme proposes research that will capitalize on this investment.

**Projected deliverables:** Large-scale research partnerships will enable improved description of genetic variation and biodiversity, allow better monitoring of animal population and environmental gene flow, and support MAS and genome-wide approaches to breeding. This will optimize production and environmental efficiency, improve human health and assist in the creation of valuable new tools for managing disease and animal health. In addition, the ATAG theme will foster bioinformatic and biological sample repositories as well as animal registries to optimize resource use and access in current and future genomics research. These repositories will not only support genomics research, but promote traceability and support Canada's competitiveness within the global food industry. ***Consultation with industry and the research community has determined that advances enabled through this theme will deliver a 25% increase in healthy animal production*** – a critical need in the face of increasing costs of production, health, and expanding global food demands.

**The budget:** This theme offers excellent value on investment and makes use of existing infrastructure and sustains long term wealth creation for the nation. A national program budget of \$120-150 million would enable at least 10 -15 major, four-year projects with a budget range of \$5 - \$20 million, sourced from 30 – 40 applications. Based on provincial and industry enthusiasm, and international opportunities, this theme could assume a 50/50 funding formula, thus leveraging Genome Canada's contribution of between \$60 and \$75 million.

# Introduction to Canadian Animal Genomics

Agriculture is the foundation on which the bio-economy is built. Countries which allow their agricultural base to deteriorate over the next 10 years will not be able to participate in the new wealth creation.

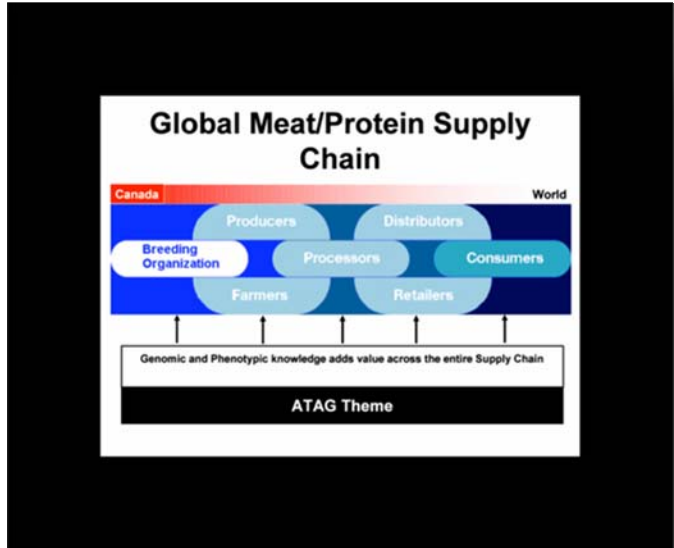
Canadian Agri-Food Policy Institute, 2007 

## The unmet need and the promise

Animal-based industries including aquaculture<sup>1</sup> are critical sectors to Canada’s economy. This fact is illustrated by the strength of Canada’s exports and industry related employment. One in eight Canadian jobs is directly related to food and agriculture<sup>1</sup>. In 2006, red meat, poultry, seafood and dairy industry sales totaled \$37.2 billion<sup>2</sup>. This position is underpinned by Canada’s reputation for the safety and quality of its animal products. Canada has benefited from its growing strength in animal genetics, which has impacted trade in breeding stocks as value-added products. The nation has the expertise and the abundant natural resources such as land, water and geographical isolation to further strengthen the Canada Brand<sup>3</sup> for food and agriculture products. Canada’s arable land per person is the second highest on the globe and is nearly double that of competing nations such as Argentina, Brazil and the United States<sup>4</sup>. Canada has 25% of the world’s coastline<sup>iii</sup> and 16% of the world’s fresh water<sup>iv</sup>, and 0.4% of the planet’s aquaculture, yet it is the 5<sup>th</sup> largest seafood exporter, by value<sup>v</sup>. Its fisheries and aquaculture industries produced over \$3.7 billion and \$902 million in 2006<sup>5</sup>, respectively. Red meat and live animal exports bring in more than \$6.2 billion annually<sup>vi</sup>. Animal production provides many thousands of jobs in coastal, rural, and aboriginal communities<sup>vii</sup>. Genomics tools have started to have a significant impact on these industries. ***Maintaining and improving production quality, efficiency and the sustainability of animal agriculture and aquaculture in accordance with consumer demand, international need for protein (835 million people malnourished and at risk of starvation globally<sup>6</sup>), and with respect for the environment is the goal of the ATAG theme’s projects.***

From conception to consumption, genomics has begun to influence all stages of livestock production and the potential of approaches such as marker assisted selection and marker assisted management have been demonstrated<sup>viii</sup>. Selection for animals that are naturally calm and produce less appetite-reducing neuropeptides will result in faster weight gains, and enhanced worker safety and animal welfare. Canada is an international fisheries and aquaculture genomics leader, as evidenced by a \$40M investment for international projects on fish species that are important to the Canadian economy: cod, halibut and salmonids<sup>ix</sup>. Canada’s investment in salmonid genomics, (GRASP and cGRASP), has resulted in the creation of world-class genetic resources that have revolutionized international research in areas such as salmonid growth, reproduction, and immunity. In 2008, Canadian bovine genetics research in Quebec, Ontario, and Alberta delivered new genomics based breeding tools for producers and industry that improve animal health and profitability<sup>x</sup>.

Future research holds promise for providing tools to augment our current strengths in areas such as food safety and quality, wild species management and genetic conservation, animal health, and for increasing biological knowledge through insights into human health and disease issues, including zoonoses<sup>7</sup>. Over the next decade, animal genomics



<sup>1</sup> Definition – Animal: any member of the kingdom Animalia

<sup>2</sup> Exporting to over 125 countries Canadian Meat Council, Industry Statistics, 2007

<sup>3</sup> “Quality is in our nature” www.brandcanada.agr.gc.ca

<sup>4</sup> Canadian Agri-Food Marketing Council, 2007 annual report

<sup>5</sup> StatsCan fisheries statistics 2006, [www.dfo.mpo.gc.ca](http://www.dfo.mpo.gc.ca); CMC Industry Statistics 2007, p 6.

<sup>6</sup> OECD FAO joint news conference, Food Emergency, June 12, 2008

<sup>7</sup> Definition – Zoonoses: diseases that cross from one species to another (humans in particular). The H5N1 strain of bird flu is an example.

research will determine the Canadian industry's future international competitiveness. Canada's researchers in this field are among the best in the world; the research community has the required technologies, expertise, animal resources and physical infrastructure in our Genome Centres<sup>xi</sup>, universities, research institutes, federal research labs, and companies to achieve the goals of this theme. Canada also has considerable strength, resources, and support available in its animal based industries. The next steps in the development of national resources by the Canadian research community are to solve priority issues, establish networks and to address emerging issues on a timely basis. A strong national program is now needed to co-ordinate these world-class facilities and research groups, and to fulfill the potential of animal genomics, in order to create tangible outcomes that benefit Canadians now and in the future.

Although world food animal production continues to grow, it is failing to meet demand. The industry is characterized by increasing food prices and reduced profitability for Canadian producers. The global outlook through 2017 for meat, including fish, is characterized by substantial increases in production and consumption in developing countries and a more stable path of development in the mature markets of the 30 member countries of the Organization for Economic Cooperation and Development. Meat consumption in developing countries is expected to account for more than 80% of global growth in meat commodities over the next decade. High international prices of dairy products will transmit strong signals for supply response from both traditional and emerging exporters. The highest growth rates of between 40 and 50% over this period are projected predominantly for vegetable oils and for livestock products<sup>xii</sup>.

The cost of coarse grains that form the feed for most farmed animal species are expected to rise from the already currently high level, creating profitability challenges for producers that can only be met through improved feed utilization. High throughput, molecular phenotyping research will identify novel phenotypes, and create improved understanding of the biological processes that influence productivity including digestion, stress and immune response. Improved feed use also results in reduced emissions of greenhouse gases and minerals, issues of domestic and international importance to consumers and governments.

#### **Delivering on the promise: 25/25 – more, better, healthier animals at lower cost**

*This theme will deliver 25% in new wealth and savings by 2025.* Canadian researchers will chart genes and genetic variations in livestock as well as sample wild populations to gain insight into the translation of genetic information to phenomic traits of interest, including growth rates, flesh quality, immune system responsiveness, and metabolic functions. They will use the substantial genomics tools created through previous Canadian investments and build on the international knowledge base that Canadian researchers have contributed to in the past. These highly qualified researchers will identify genes, molecular pathways, biological processes and their interactions with environmental factors through the use of high-throughput technologies including proteomics, metabolomics and metagenomics to study the microbiome of these animals and through the collection and management of data using bioinformatic computing tools. They will use comparative genomics to take advantage of previously sequenced genomes in livestock, fish and other species, including human, and to analyze and measure polymorphisms at locations genome wide.

Using microarray technology, they will measure large-scale gene transcription and using state of the art facilities and national and international resources, they will seek the genes and other genomic regions that are responsible for commercially important animal traits using high-throughput technologies such as single nucleotide polymorphism (SNP) genotyping. Canadian scientists funded through this theme will use quantitative trait loci and gene mapping to identify chromosome regions that influence these traits of interest and then drill down to the causative mutations themselves. Microarray and proteomic analysis tools will continue to lead scientific investigators to find expressed patterns that function across species and lead to the unraveling of the physiological regulation of traits that will protect and provide for Canadians on farms, in rural and aboriginal communities, the industrial processing, transportation, export and grocery sectors. By taking a coordinated approach, Canadian researchers will be able to optimize the value of the research, ensuring that the best value is obtained from each set of animal resources. For example, by using high throughput analyses to help characterize and categorize key animals and their environments in novel ways.

**Transcriptomic analysis has revolutionized the way Hills Pet Nutrition develops its products. It helps us identify stratification within phenotypic groups as well as identifying markers to be monitored in our clinical trials.**

*Mitch Abrahamsen, Vice President Research, Hills Pet Nutrition Inc.* 

This molecular characterization will allow the animal production industry options to develop the traits that will improve profitability and sustainability through the selection and breeding of animals that naturally meet the needs of the market and society, improvement of digestion and feed utilization to reduce input costs and the environmental footprint. Improved food safety and reduced zoonotic threats to society will be achieved. It will provide government with tools to manage wild stocks for supply and genetic diversity, regulate food safety and create policies that serve the public good. Research opportunities will develop, attract and retain the highly qualified people necessary to the successful, sustainable expansion of the economy and the academic institutions that educate and illuminate. The theme builds international research collaborative opportunities with Canada’s largest trading partners, the U.S. and EU.

Genomics research under this theme naturally requires it to be environmentally, ethically and legally sustainable. By its very nature, it creates a wealth of opportunities for GE<sup>3</sup>LS inquiry in the identification and value of desirable traits and attributes, animal welfare, novel trait creation, environmental protection, community development and intellectual property protection.

**Livestock genomics is moving incredibly quickly. The progress made in the last 12 months would have been regarded as science fiction last year. The direct involvement of Canadian groups in Guelph and Alberta has been essential in ensuring Semex is part of this new wave. The future opportunities are immense. We are committed to the development and application of genomics in the bovine industry and I believe Canada has a fantastic opportunity to take a world lead for all farmed species. Such a lead will help Canada play its role in securing the world’s food supply.**

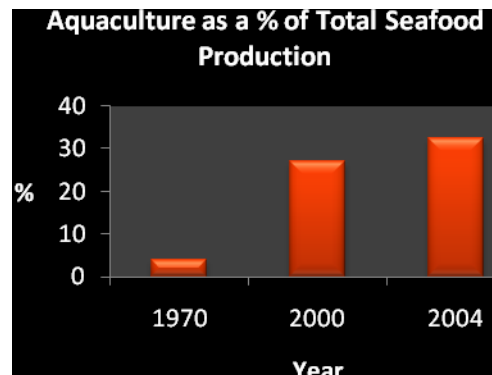
*Jacques P. Chesnais, Senior Geneticist, The Semex Alliance* 

The research developed within this theme will create a knowledge base critical to improvements in animal production, improved human health outcomes and industrial and export food processing creating more than \$8 billion annually by 2025. ***Sustainably increasing animal-protein production is necessary to international political stability and the welfare of the planet.*** Genomics research through the ATAG theme will substantially aid the nation in meeting that international food obligation. The ATAG theme paper highlights the pan-Canadian importance of this research area, focusing on the social, the market, the sustainability, and the strategic significance. Elaborating on the need for research in terrestrial and aquatic animal genomics, the ATAG theme’s vision is to co-ordinate large-scale research that capitalizes on Canadian strengths, harnesses industry resources, and expands the nation’s capacity for the physical characterization of animals. GE<sup>3</sup>LS research opportunities are highlighted throughout this paper, with emphasis on enabling communication and knowledge utilization. Finally, expected outcomes and impact are outlined, and a budget is proposed. This theme is well aligned with Industry Canada’s recently released framework for Mobilizing Science and Technology to Canada’s Advantage and is a reflection of the large and diverse multi-sector and multi-national input that has been incorporated into this document.

## Delivering at Home: Leading the world

### In cod we “trust”

Traditional fisheries provide an important basis of cultural and economic activity in Atlantic Canada, although the fisheries for some species such as Atlantic salmon and Atlantic cod have severely declined. The decline in Atlantic salmon stocks served as an incentive to develop today’s aquaculture sector, which generates more than \$200 million in annual revenue in New Brunswick alone. The contribution of aquaculture to global supplies of fish, crustaceans, mollusks and other aquatic animals continues to grow, increasing from 3.9 percent of total production by weight in 1970 to 27.1 percent in 2000 and 32.4 percent in 2004. Aquaculture



continues to grow more rapidly than all other animal food-producing sectors. Worldwide, the sector has grown at an average rate of 8.8 percent per year since 1970, compared with only 1.2 percent for capture fisheries and 2.8 percent<sup>4</sup> for terrestrial farmed meat production systems over the same period. Production from aquaculture has outpaced population growth, with per capita supply from aquaculture increasing from 0.7 kg in 1970 to 7.1 kg in 2004, representing an average annual growth rate of 7.1 percent<sup>xiii</sup>. Canada's under-utilized coastal environment provides vast opportunity for growth of the sector.

One approach towards maintaining growth and stability of the aquaculture industry is diversification into rearing other species such as Atlantic cod. Several Canadian institutes, including Memorial University, Huntsman Marine Science Centre, St. Andrew's Biological Station, NRC Institute for Marine Science, The Atlantic Genome Centre, and the Universities of Guelph, New Brunswick, and British Columbia have partnered for the Atlantic Cod Genomics and Broodstock Development Project (CGP). Cod breeding programs are also being developed in countries such as Norway and Iceland. The Canadian aquaculture industry recognizes that broodstock selection is essential in order to produce superior cod stocks for farming. The CGP is a partnership with industry, universities, government and not-for-profit organizations and will apply genomics technologies combined with family-based selective breeding methodologies to identify cod with traits of commercial importance, such as improved growth, delayed age of sexual maturation and resistance to disease and stress. The project will sequence genes in order to identify molecular markers that are associated with superior performance under farming conditions. A substantial investment has been made by Genome Canada and other partners to fund the CGP ([www.codgene.ca](http://www.codgene.ca)). The CGP is developing genetic tools and markers to enable the selection of broodstock with desirable traits for cod aquaculture. The deliverables for the CGP include elite cod broodstock selected for performance in industrial scale aquaculture production as well as a set of genomics tools and a genetic map that can be used to identify quantitative trait loci (QTLs) for accelerated enhancement of cod broodstock. This research will give Canada a competitive edge in the developing cod aquaculture industry by ensuring that Canadian producers will have tools to improve the quality and volume of their product.

#### **A GRASP of the concept**

Canada is the world leader in salmon genomics. The international consortium for Genomics Research on All Salmonids Project (cGRASP) is co-led by researchers from the University of Victoria, Simon Fraser University and the Centre for Integrative Genetics at the Norwegian University of Life Sciences. The consortium has developed physical BAC maps, over 430,000 salmon and 180,000 trout ESTs (19th and 29th largest collections for all species), 32K cDNA and 22K oligo microarrays, genetic maps and >4000 SNPs, as well as over 10MB of genomic sequence. Broodstock programs using these resources are being developed in British Columbia to compliment programs in Norway and Chile. Recently, Canada, Norway and Chile have funded a whole genome sequence project that will provide a reference sequence for the 68 different Salmonid and trout species, many of which are of commercial interest. Canada has taken a leadership role in developing genomic tools for one of the most widely studied and economically important species of fish and is in an excellent position to continue to develop these resources for uses in conservation of wild stocks and ecosystems, environmental assessment, health and aquaculture.

**Sound science is the foundation on which the government manages the diverse range of human activities in our waters, including fishing, aquaculture, transportation, and oil and gas exploration. Because these decisions can affect people's lives in a variety of ways—from the livelihood of Canadians in coastal communities to the protection of the environment for current and future generations—decisions must be based on the highest-quality science available. In turn this requires cutting-edge technology in the hands of top-notch researchers, long-term monitoring, data management and the ability to interpret and transform new knowledge into sound science advice.**

*Canada's Federal S&T Strategy 2007* 

#### **Who's the "Bos"?**

Even with the best conventional breeding and reproduction technologies, including artificial insemination, embryo transfer, and DNA markers to track elite alleles for desirable production traits, it still takes five years from conception to

produce a new bull calf, rear it to sexual maturity and progeny-test its offspring. Seeking the best tenderness and human health friendly meat qualities requires livestock slaughter prior to testing, making breeding the best animals a challenge that even geneticists find daunting. The use of genomics tools and other advanced technologies potentially compress that entire cycle into just a few weeks, and have the first superior new calves born in little more than a year.

Based at the University of Alberta, Beef Genomics Initiative's (BGI) research is aimed at using structural and functional genomics approaches to study the bovine genome, including marker development, gene mapping, QTL studies and gene expression analysis. Establishing new frontiers in knowledge in the field of bovine genomics, BGI is also developing applications that will have significant impact on the beef cattle industry, both locally and abroad. With approximately 30 scientists involved and a number of international partners the project, begun in 1999, is led by the Canada Beef Industry Development Fund chair in beef genomics. The beef genomics program aims to develop an understanding of how genetic variation in cattle populations can be used to increase the production efficiency and quality of beef while reducing waste outputs such as CO<sub>2</sub>, methane and manure. The identification of animals that eat less food, finish better, and produce less waste will benefit all sectors of the industry and the environment. Specific programs underway include the identification of genes affecting growth and fat deposition and the identification of genes affecting the efficiency of nutrient utilization. In order to enhance the ability to find such genes in cattle, a basic research program, developing a high-resolution gene map of the cow is well underway. This program, in collaboration with groups around the world, will build the foundation onto which all the genes in cattle will be identified. At the same time attention is being paid to identifying the phenotypic variation in research and commercial populations of cattle. Cattle populations at the University of Alberta Ranch, at AAFC and Agriculture, Food and Rural Development (AAFRD) along with large industry populations are being used in this study. Combined with a detailed knowledge of the molecular genetics of the cow, data on phenotypic variation will enable the assignment of function to genes relevant to industry issues. Canada is also involved in the early stages of metagenomics research of digestive processes in the rumen and gut which offers new opportunities to understand the interaction between host and its microbiome and the impact on animal performance, well-being and product quality.

At the University of Guelph, the Canadian Dairy Network (CDN) and at AAFC in Laval, Quebec researchers have developed a multiple trait linear animal model tool the Canadian dairy cattle industry has been anticipating since 2004. The Reproductive Performance genetic evaluation system was launched in January of 2008. It evaluates female fertility and calving performance traits simultaneously. A major advantage of this approach is that it considers the impact that calving difficulty can have on the subsequent fertility of the cow. In addition, the higher heritabilities of the calving performance traits, helps improve the accuracy of the genetic evaluations for the correlated measures of female fertility. Other genomics research at Guelph (with Alberta) includes the creation of genome wide estimated breeding values that would replace traditional female and male genetic EBV evaluation systems. This research could potentially reduce the cost of proving bulls by 92 percent and double the rate of genetic change and adaptation. Genomics research has also identified SNP that appears to be a reliable indicator for animals that have a complex genetic make-up that makes them resistant to mastitis which costs North American dairy producers \$1.5 to \$2 billion annually<sup>xiv</sup>. The CDN has also recently launched a centralized dairy cattle tissue sample based DNA databank to improve the national herd by exploiting both small sets of DNA markers for performance traits and genome wide selection using large panels of markers.

**A recent direction taken by Canadian Dairy Network is the priority placed on the application of genomics to increase the accuracy of the genetic evaluations in dairy cattle in Canada, starting in 2009. The theme of this research position paper is a perfect fit to realize this goal.**

*Brian Van Doormaal, General Manager, Canadian Dairy Network, June 2008* 

### Network news

The EmbryoGENE Network was created in order to address important issues concerning embryo development in livestock, mainly cattle and swine. This concerted pan-Canadian effort, supported by NSERC (Natural Sciences and Engineering Research Council of Canada), is devoted to understanding the genome and epigenome of the normal embryo and to determine how maternal nutrition, and the environment of the embryo during the application of Assisted Reproductive Technologies (ART; such as hormonal stimulation of follicular development, in vitro fertilization, in vitro culture, cloning, transgenesis, intracytoplasmic sperm injection, etc.) influence developmental competence of the early embryo and as a consequence, the future health of offspring derived from such embryos. The Network, led by Laval University and the University of Alberta, is composed of 19 investigators representing seven universities. The Canadian

Food Inspection Agency, AAFC and eight industry partners are also participating in the Network. Through high-throughput approaches using transcriptome and epigenome comparisons, the effort of the EmbryoGENE Network sheds light on the effect of human intervention in reproduction and will provide new ways to improve embryo health.

Considering the economic impact of Assisted Reproductive Technologies (ART) in animal agriculture, the EmbryoGENE project appears very relevant, especially in the context where major concerns are raised regarding the application of ARTs to food-animal production. The data generated by the Network serves the public by providing them with information on the health of animals on our farms. The EmbryoGENE network also provides the regulatory agencies with new data to rely on for their decision-making processes. Furthermore, research efforts of the EmbryoGENE Network provides the industry with new insights on how to minimize the impact of embryo manipulation on embryonic development and thus improve embryo quality and consequently, the health of offspring, their commercial value and human health improving food qualities produced with the use of reproductive technologies.

## This Theme for This Canada

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### The all-consuming public

Consumers are increasingly aware of the role that processed food plays in chronic diseases like obesity, diabetes, and cardiovascular disease. With SARS and H5N1, the risk of infectious disease associated with food or animal products has increasingly been in the public eye. The meat industry, in particular, has also been challenged over potential links between red meat consumption and cancer incidence. A 2003 Globescan report showed that China, Canada and the USA, all put food safety and nutritional value above price<sup>xv</sup>. This heightened awareness has manifested in rapid changes in both producer and consumer positioning in the food market place. Genomic approaches will help improve the understanding of basic biological processes and the influence of the environmental aspects that will play an increasing role in helping assure food safety and quality. Concerns about the welfare of farm animals have also been increasing in recent years. In a large European Union survey of over 29,000 respondents<sup>xvi</sup>, 34% said that animal welfare was of the highest possible importance. The consequences of such attitudes are important factors in Canada's global competitiveness. A demand for higher animal welfare standards places pressure on export countries like Canada. Genomics provides opportunities for enhancing animal welfare, for example by reducing or eliminating traits and behaviors, such as aggressiveness, that lead to preventable animal suffering. A key goal of the ATAG theme is to harness the power of genomics to ensure the efficiency and health of Canada's animal resources.

### Marketplace significance

Animal-based industries including aquaculture<sup>8</sup> are critical sectors to Canada's economy. This fact is illustrated by the strength of Canada's exports and industry related employment. One in eight Canadian jobs is directly related to food and agriculture<sup>xvii</sup>. In 2006, red meat, poultry, seafood and dairy industry sales totaled \$37.2 billion<sup>xviii</sup><sup>9</sup>. Canada has benefited from its growing strength in animal genetics, traceability and disease response systems, which has impacted trade in breeding stocks as value-added products and has the expertise and the abundant natural resources such as land, water and geographical isolation to further strengthen the Canada Brand<sup>10</sup> for food and agriculture products. Its fisheries and aquaculture industries produced over \$3.7 billion and \$902 million in 2006<sup>11</sup>, respectively. Red meat and live animal exports bring in more than \$6.2 billion annually<sup>xix</sup>.

The FAO estimates that by 2025 the annual demand for seafood and fish protein will surpass the capacity of the wild fishery by approximately 55M tones, and to compensate for the shortfall, aquaculture production will have to increase by about 350%. Wild capture fishery potential from the world's oceans has probably been reached and as a result, fish farming continues to grow more rapidly (8.8% compared to 1.2% for capture fisheries and 2.8% for terrestrial farmed meat, since 1970) than all other animal food-producing sectors<sup>xx</sup>. Based upon predicted market trends, productivity increases, and the estimates of capable aquatic resources Canadian aquaculture production growth will likely accelerate to

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<sup>8</sup> Definition – Animal: any member of the kingdom Animalia

<sup>9</sup> Exporting to over 125 countries Canadian Meat Council, Industry Statistics, 2007

<sup>10</sup> "Quality is in our nature" [www.brandcanada.agr.gc.ca](http://www.brandcanada.agr.gc.ca)

<sup>11</sup> StatsCan fisheries statistics 2006, [www.dfo.mpo.gc.ca](http://www.dfo.mpo.gc.ca); CMC Industry Statistics 2007, p 6.

15% per year with a resultant production of 577,000 tonnes valued at \$2.8 billion by 2010-2015<sup>xxi</sup>. Current Canadian aquaculture production volume is dominated by salmon (67%), mussels, oysters, and trout. Canada produces 6% of the world production of salmon and nearly 8% of the value. Other types of finfish grown in aquaculture are trout, char, Atlantic halibut, sablefish and cod. Current cod production in Canada is about 1000 tonnes; although, the Department of Fisheries and Oceans (DFO) estimates that cod aquaculture could grow to 50,000 tonnes within 10 years. In 2004, the value of the fish crop reached nearly \$527 million with the value of exports reaching \$425 million, 81% of the total and more than twice the value a decade earlier. Genomics tools will help reach aquaculture production targets and provide new tools to monitor the health of fish crops and wild populations.

Canada has the potential to be a world aquaculture leader. Aquaculture is a new economy, high value industry, grounded in science and technological innovation. The challenge for the Canadian industry is to create the conditions necessary to take advantage of the socio-economic potential while ensuring that the industry remains environmentally sustainable<sup>xxii</sup>.

Canada is not immune to rising global challenges associated with agri- and aquaculture; current challenges include BSE, Avian Influenza and the decline in many of the world's large fish stocks<sup>xxiii</sup>. Increasing pressure on smaller fish species that are used for fishmeal is increasing the cost of fishmeal used in aquaculture. This and other threats jeopardize Canada's multi-billion dollar fishery and aquaculture industry<sup>xxiv</sup> and many thousands of jobs in coastal, rural, and aboriginal communities. Similar pressures are also impacting terrestrial animal feed costs, as renewable energy crops begin to replace feed-crops, thereby driving up input costs in animal food production. Canada is the third largest exporter of pork in the world, with 50% of production moving to 100 countries<sup>12</sup>. The global pork exports have tripled in the last 15 years and there is a need for leading-edge technology for Canada to maintain its competitive position.

## GE<sup>3</sup>LS

Public surveys consistently show greater public concern for animal genomics and biotechnology than for plant genomics and biotechnology<sup>xxv</sup>. GE<sup>3</sup>LS research emphasizes the potential of animal genomics benefits for Canadian citizens and the economy. For this theme, it is critical to understand the ethical, environmental, economic, legal and social implications of potential approaches to and outputs from animal genomics research. This theme will draw upon the internationally recognized Canadian GE<sup>3</sup>LS community develop both integrated and stand-alone GE<sup>3</sup>LS projects that are relevant to the science of animal genomics.

Canada has experience with regulation and debate about transgenics in livestock and the potential benefits to and concerns of its society. A recent review of Canadian GE<sup>3</sup>LS research and interviews with Canadian GE<sup>3</sup>LS researchers suggest a number of key social science and humanities research areas in animal genomics that are ripe for study<sup>xxvi</sup>. The most commonly cited research areas were governance and social acceptability, including risk assessment, public perceptions and concerns, policy and regulatory responses, and public engagement. Industry Canada's framework for Mobilizing Science and Technology calls for Canada to become a "best-in-class regulator"<sup>xxvii</sup>. Other research areas include industry innovation strategies and associated employment and economic growth, the capacity for regulatory responses to developments in animal genomics in light of rapid scientific developments, potential environmental risks, animal health and welfare, knowledge translation to communities and policy-makers, and global equity.

The animal protein sector is embedded in rural and coastal regions and Canadians, including aboriginal peoples, rely on farmed and wild caught animal industry for the sustainability of their communities' economies and cultures.

Economic value is the basis for this theme's research endeavours, its attractiveness to investors, inside and outside of the public sector. The theme offers opportunities for economists to examine the downstream effects of genomics discovery and validate the need for and outcomes of the research at all levels. Opportunities exist to provide researchers with economic value guidance by modeling single points on a value chain for marker assisted selection decisions. The market potential of Canadian marker-based intellectual property and the legal strategies that protect that IP are issues that arise from and form part of this theme.

Throughout genomic research there is a need to better understand public values, perspectives and perceptions on key technological, policy and ethical issues. The tie of genomics research to economic outcomes is often missed by the public. This theme creates an opportunity to inform Canadians about the role of science in their personal health, wealth and culture.

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<sup>12</sup> Canadian Pork Story, [www.canadapork.com.ca](http://www.canadapork.com.ca).

## Water, waste, want: The environmental “foodprint”

While animal and land resources continue to decline, rapid expansion in the demand for animal protein will continue to create substantial economic and environmental challenges. In most developing countries, agriculture is the most water-intensive sector of the economy and, unlike manufacturing, consumes much of the water that it uses<sup>xxviii 13</sup>. As a result, water tables are now falling in countries that contain over half the world's people. Future water shortages will make it much more difficult to produce enough food to stay ahead of rising consumption. Urbanization and renewable energy land usage are also growing concerns. At the same time there is an opportunity to address greenhouse gases, which are a significant by-product of the animal industry. There is a critical need to optimize animal-based agriculture in ways that reduce the environmental impact - a need that can be alleviated, in part, by genome-based selection of production animals.

Logic suggests that water-intensive activities should be undertaken in water-rich locations. Economic arguments against moving grain to animals are even more compelling. Canada possesses some of the world's largest reserves of fresh water, a considerable proportion of the world's arable land, and an animal population density second lowest on the planet, a significant benefit to biosecurity and animal health.

Importantly, Canada also has access to a considerable diversity of animal species, a critical resource for the long-term sustainability of production populations. Together with advanced genomics capabilities and value-added genetic leadership ability, Canada is well positioned to assume a significant international role in developing enhanced sustainability resources and practices in the agri- and aquaculture industries. Canada is already home to international genetic nucleus herds, the very top of the genetic pyramid, for pig, poultry and cattle.

### ENVIRONMENTAL SUSTAINABILITY

**Genome-based selection of production animals can optimize animal-based agriculture in ways that helps reduce the environmental impact.**

## Strategic biological security

Food safety, security and supply are critical national strategic concerns. Major issues associated with animal-based industries include diseases that affect the food supply and human health. Growing global food demands require ever-larger sources of animal-based resources, leading to the intensification of agriculture and aquaculture practices. Disease is a particular threat to these large-scale operations, especially in populations with relative genetic homogeneity. Farmed fish populations are especially vulnerable to diseases such as the infectious salmon anemia virus, which can lead to widespread mortality. Terrestrial animals, particularly those raised in high population densities, are also susceptible, as demonstrated by a recent epidemic of Porcine Reproductive and Respiratory Syndrome virus, which claimed 1 million pigs in China as recently as 2006<sup>xxix</sup> and remains a threat to global pig populations.

The intensification of agriculture and the increase in trade brought about by globalization is also causing the emergence of new, life-threatening zoonotic diseases. Researchers report that 80% of emerging public health challenges are zoonoses (human infections arising from animal sources)<sup>xxx</sup>. Exemplified by SARS, 38 diseases have made the jump from animals to people in only the last 25 years<sup>xxxi</sup>. Experts in the field of infectious disease believe that intensification of animal rearing, the competition of humans and animals for space, and climate change are causing increasingly more virulent strains of pathogens to emerge and sweep across continents. Currently, the greatest zoonotic threat – H5N1 avian flu - has emerged largely due to the high density and proximity of animals and people in Asia. BSE demonstrated that being free from reportable disease is a critical success factor for the North American animal industry.

Diseases are not the only threat to food production. Increasingly, centralized food production and processing systems create the potential for significant widespread food-safety problems. The CDC identified 17,252 confirmed cases of food poisoning in 2006, including 6,655 cases of Salmonella and 590 cases of *E.coli* O157<sup>xxxii</sup>.

Genomics technology offers potential solutions for maintaining and expanding global animal resources by providing information to increase efficiency, fight disease and improve biosecurity. A new understanding of host-pathogen interactions based on genomics research offers the promise of improved vaccines and disease immunity, new gene-based targets for treatment, better response times to new threats and the potential to breed healthier animals. The latter may produce animals that better respond to vaccination, or carry a lower burden of zoonotic organisms, so that greater food safety can be delivered through the food chain. At the same time, genomic information and infrastructure will provide a

<sup>13</sup> Less than 30% of the water used is returned to sources such as rivers and lakes (Ref 16).

critical component to advance biosafety programs with improved traceability, allowing rapid identification of disease outbreaks or food chain contamination.

## The Challenge for Canadian Genomics

### The need for right-sized research

Realizing the promise of genomics for animal-based industries requires a rate-step change in Canada's approach to genomics research. Canada's previous investments have laid the foundation and demonstrated the tremendous potential of this technology. However, an integrative pan-Canadian approach is now required to implement truly large-scale research and fully address the needs and opportunities of the animal-based industries. Information about how the genetic make-up of an animal impacts its physical characteristics or phenotype is critical to harnessing genomic information, but is difficult and expensive to quantify. This is creating opportunities for molecular phenotyping using genomics tools such as microarrays for expression profiling. The large-scale collection of genomic-phenotypic data coupled with an IT-driven bioinformatics platform represents a critical next step for Canada's animal genomics research communities. Critical investments are necessary to create high quality reference sequences as part of international consortia, so that collected phenotypic data can be appropriately matched to a complete, high confidence genomic map. Both efforts require an integrated approach<sup>14</sup> with the participation of all sectors in order to achieve the necessary scale. Only through a large-scale biology approach will researchers be able to tackle global problems, develop greater insights, and make faster progress than is possible by using only models or experimental systems. The ATAG theme addresses this timely need.

**I see the science of genomics as the salvation for most of the major issues facing society today, from human and animal health to sustainability in all its forms including energy, carbon, water and greenhouse gases. It is the knowledge of genomics that will re-balance the ecology. To me, this is the big picture reason why Canada must allow this animal genomics research initiative to go forward, and in so doing regain its lost competitive advantage in agri-food.**

*John Webb, Director of Genetics and Science, Maple Leaf Foods Inc., June 2008* 🇨🇦

The sustained development of genomic approaches in medicine has led to breakthroughs in understanding the molecular basis of human diseases. Parallel research in agriculture is beginning to impact farmed animals though the identification of production-relevant traits such as milk production, meat marbling and feed efficiency. Likewise, continued development of genomic resources for animals, coupled with an integrated effort to collect richer phenotypic information, including information on the environments where animals are produced, together with experimental and commercial applications of these tools and integrated GE<sup>3</sup>LS research, will allow Canadian scientists to retain their current competitive edge and to build upon established interactions with complementary international programs in the U.S., EU, Australia and NZ for pigs and cattle and Norway, UK and Japan for fish. This approach is in line with international best practices, exemplified by the UK BioBank and the Wellcome Trust Case Control Consortium (WTCCC), which recently reported the analysis of almost 10 billion pieces of DNA, collected from 17,000 people. Their findings reveal novel insights into complex disease that would not have been possible without this scale of research<sup>xxxiii</sup>. The ATAG theme will create the animal equivalents of the BioBank and WTCCC, and its scope will be beyond common diseases. Although this is extremely ambitious, progress and exploitation of past investments can only be made through such an effort where detailed information is collected on large numbers of animals. The challenge is such that a program as envisaged here would place Canada at the forefront of this animal genomics research, providing many of the strategic benefits set out in the Federal Science and Technology Strategy. The promise of this approach is illustrated by the speed with which Mendelian mutations could be identified in cattle using the 50k bovine SNP chips developed in 2007<sup>xxxiv</sup>. The proposed research will provide essential information for Canadian industry, stakeholders and policy makers to address rising international competition and to focus on climate change, environmental footprints, food safety and sustainability.

<sup>14</sup> Also advocated by Industry Canada (Ref 23).

## Timely investment

The plummeting cost of gene scanning and the emergence of gene chip technologies over the last 2 years make this a better time than in the past to realize the promise of genomics for animal research<sup>xxxv</sup>. The Bovine Genome Sequencing project provides a good example in the recent development of the 50,000 SNP chip, an important resource that has tremendous value and application in high throughput technology. Recent advances in research technologies have cut time and cost of discovery substantially, allowing researchers to achieve results at an ever more rapid rate, for example the drilling to Mendelian mutations in cattle using the 50k SNP chip. By addressing an existing phenomic roadblock in livestock information, this theme will quickly be in the same position as human health researchers who can scan the genomes of thousands of people and, by comparing the clinical and physiological profiles of sick and healthy people, uncover markers for diseases such as diabetes, cancer and Alzheimers<sup>24</sup>. This theme, will capitalize on state-of-the-art techniques developed in medical genomics by applying them to animal research. By scanning the genomes of thousands of animals in different environments, and by comparing different phenotypic classes - sick with healthy, efficient with inefficient, desirable with undesirable - researchers will uncover markers and environmental influences they can use to deliver healthier, higher quality, sustainable food to Canada and the world. Epigenomics and metagenomics are critical research components to the value of this theme.

Large-scale population genomics will be statistically powerful. The ability to collect multiple sets of information on the same animal and its relatives means that animal researchers can drive forward with a speed and breadth of focus that exceeds that found in human genomic research. For example, the theme will allow researchers to know the impact of a gene variant that contributes to reduced load of Salmonella on traits such as feed conversion, organ function, physical conformation and overall longevity. Research will also be able to tease apart the interactions between genotype and environment, including nutrition or disease treatment, which will in turn provide benefits in improving human health. Creating these foundational resources will be a critical feature in fostering investment and creating a climate that encourages entrepreneurship and private sector investment.

## Capacity Highlights

Canada's tremendous potential for genomics and existing value added genetic capabilities are attributed largely to previous and ongoing investments by Genome Canada, the regional Genome Centres and co-funders. Canada also has a long history of successful investment in animal genetics and production. Several projects in particular highlight the current level of interest and strategic leadership already initiated by, or related to, investment by Genome Canada: The consortium for Genomics Research on All Salmonids Project (cGRASP), The Cod Genomics and Broodstock Development Project (CGP), Pleurogene (halibut), Functional Pathogenomics of Mucosal Immunity (FPMI), Pathogenomics of Innate Immunity (PI2) and the Alberta Bovine Genomics Program, including the Genome Canada investment in the international bovine genome sequence consortium. Genome Canada has funded successful GE<sup>3</sup>LS research projects related to animal genomics including both large-scale stand alone and integrated GE<sup>3</sup>LS research projects<sup>xxxvi</sup>. The GE<sup>3</sup>LS component of Advanced Foods Materials Network highlights the successful investment in GE<sup>3</sup>LS related to food, health and biotechnology<sup>xxxvii</sup>.

Achieving coordination of resources is an important concept in this theme. In particular, this theme will focus on enabling effective cross study analysis between large scale population studies and small scale studies with the aim of complimenting both resources. This will require similar measures of traits and environmental factors or the use of genetically related individuals. Accordingly, the theme will seek to include a coordination activity, with an integrated strategy for sample collection and analysis, to support the animal genomics initiative and maximize the use of the resources as they are developed. Genome Canada has already pioneered the development of such approaches with BioMoby: <http://www.biomoby.org>, by supporting the creation of bioinformatics networks and infrastructure that can support bioinformaticians embedded within research groups and their laboratories. By harnessing these dispersed infrastructure pieces, it will be possible to create an integrated community of animal researchers able to mine the assembly of resources without the need for extensive additional IT infrastructure. Furthermore, linkages with

### CANADIAN CAPACITY

- ✓ Genomics Research on All Salmonids Project (cGRASP)
- ✓ The Cod Genomics and Broodstock Development Project (CGP)
- ✓ Pleurogene (Halibut)
- ✓ Functional Pathogenomics of Mucosal Immunity (FPMI)
- ✓ Pathogenomics of Innate Immunity (PI2)
- ✓ Alberta Bovine Genomics Program
- ✓ Advanced Foods Materials Network

human health research will extend the utility of these resources to both animal and human researchers for an added level of multidisciplinary collaboration.

**The ATAG proposal has the potential to provide tremendous benefit to the Canadian animal breeding industry. As livestock and aquaculture markets become increasingly competitive and breeders will require new means to improve their genetics.**

*Joachim Richert, CEO & Managing Director DNA LandMarks (BASF) *

The ATAG theme is an integrative large-scale partnership approach to creating a pan-Canadian effort in animal genomics. Potential contributors to this effort include industry, government, and academic groups, as well as international collaborators. A list of industry and research organization stakeholders that support and have expressed interest in participating in this theme is available on the ATAG website ([www.genomealberta.ca/ATAG](http://www.genomealberta.ca/ATAG)). The issues and opportunities identified here are international in scope. The need for enlarging the scope of data that is collected on animal populations in order to harness genomics resources to deliver the desired outcomes is widely recognized<sup>xxxviii</sup>. New research programs exist including the Cooperative Research Centres in Australia, the European Seventh Research Framework Programme (FP7) or are being developed such as those at the USDA, that provide opportunities to establish significant international collaborations for ATAG projects. In addition, it is anticipated that there will be important opportunities to develop collaborative efforts with countries where the demand for animal protein is increasing such as China. International collaboration is likely to be an essential feature for projects that focus on genotype-environment or host-pathogen interactions. GE<sup>3</sup>LS research will provide further insight on opportunities and best practices in engaging international collaborators, and capturing maximum value from opportunities outside of Canada.

## The Budget

Canada has the capacity to conduct 10 to 15 major projects over the next four years with a budget range of \$5-20 million with a Genome Canada contribution making up half of these amounts. The research will include the establishment of several strategic reference population projects, particularly those involving large numbers of commercially relevant animals, and support for several comparative genomics projects. ATAG will naturally integrate GE<sup>3</sup>LS activity within the projects, but will also provide an opportunity for a stand-alone GE<sup>3</sup>LS project addressing the strategic needs of the theme. To meet bioinformatics needs, up to \$25 million will be included for coordination, including distributed bioinformatics and the archiving and curation of theme resources. Considering a 50/50 cost sharing funding formula, the Genome Canada contribution would be \$60-75 million, with the remaining contributions to come from industry partners, including large, in-kind animal population supplies and associated phenotypic information from producer organizations, investment from the provinces, the Canada Foundation for Innovation and international collaborators.

The ATAG theme will develop outputs that will have a significant impact on the Canadian animal industry sector. This will be achieved by improving the efficiency and health of Canadian production. Animal breeding typically generates an improvement of two to three percent annually for cattle, pigs, and poultry; from a sector that currently has a value of \$36 billion<sup>15</sup> this is a \$1.08 billion return. Advances created by and savings from the work of this theme are in part cumulative and compounding, such as production expansion in aquaculture and livestock due to improved genetics. An additional improvement of 25 percent in the decade that follows these projects will deliver an \$8 billion annual return to Canadians.

**Improvements in our quality of life and standard of living will depend on our increasing success in bringing scientific and technological innovations to life.**

*Canada's S&T Strategy, 2007 *

<sup>15</sup> Red meat \$14.6 billion [www.agr.gc.ca/redmeat/factsheet06.pdf](http://www.agr.gc.ca/redmeat/factsheet06.pdf); Dairy \$13.0 billion <http://www.dairyinfo.gc.ca/pdf/graph1.pdf>, Poultry and eggs 5.1bn [http://www.agr.gc.ca/poultry/prindc2006\\_e.pdf](http://www.agr.gc.ca/poultry/prindc2006_e.pdf) Livestock and Aquaculture; Aquaculture \$2.5 billion (see Ref 6).

## Response to reviewer's comments - ATAG 2007

The writing team was pleased to see that the overall strengths identified for the paper gave fundamental support for further investment in this field:

- “Convinced about the importance of the work.”
- “Canada is one of the few countries to be able to do this work in an open way.”
- “The tools are there to move this area forward.”
- “Work in animals linking genotype with phenotype could inform subsequent work in human health.”

The team was also encouraged by many of the individual reviewer's comments. For example, the budget was considered to be realistic and appropriate.

However, a number of weaknesses were flagged by individual reviewers. Although these were sometimes contradictory we recognize that they indicate that the paper failed to provide sufficient clarity in some areas. We have revised the paper significantly in order to address the feedback provided by the review process. In addition, we have also highlighted some of the important points here in this document in order to show how we have addressed them. Each aspect is illustrated by a quote from the reviewer's comments (RC). However, examples are used for brevity.

### RC - “This work should be an international effort”

We agree wholeheartedly with the comments on the international scope of this theme. We have tried to clarify what is required for progress and where Canada can partner internationally. We have also indicated that the current hurdles for exploitation of animal genomics are internationally recognized. An example is the Blueprint for USDA Efforts in Agricultural Animal Genomics 2008-2017 ([www.ntis.gov](http://www.ntis.gov)). These documents reflect international discussions that have included Canadian genomics researchers as well as industry groups. Importantly, we believe that the coordinated approach being proposed here provides a genuine opportunity for Canada to play an international leadership role in the next stage of animal genomics research and application. This opportunity stems from the previous investments set out in the paper as well as the importance for, and international reputation of Canada in the area of agri-food production.

### RC - “The authors point to many from government and industry who have made expressions of interest in the theme. .... need convincing on this point”

In 2007 we provided supplementary information identifying the individuals and groups who had formally supported the position paper. Although this material was available it did not form part of the main presentation. In 2008, through a multi-stakeholder workshop we have worked with key proponents of this theme to ensure input from a variety of sources including government and industry. Lists of supporter from 2007 and 2008, as well as letters of support from leaders in industry and academia, are available on the ATAG website ([www.genomealberta.ca/ATAG](http://www.genomealberta.ca/ATAG)).

### RC - “(Indicator traits need to be determined) – this can't be done in industry animals”

Complimentary approaches are required, from very detailed *in vitro* analysis (e.g. transcriptomics) to the collection of new trait information on large numbers of commercial animals (e.g. for the collection of information on health or disease susceptibility during natural disease outbreaks). Progress in genetic and genomics research requires very large numbers of samples for sufficient power and validation of results (also see next response). A lack of power was one of the reasons that initial findings and announcements of genes for different disorders in humans failed to be replicated and ultimately fell by the wayside. Through partnerships with industry and large researcher networks, this theme proposes means to ensure efficient use of research investment through optimization of information and sample access.

The revised position paper clearly demonstrates that industry is keen to partner with researchers to ensure improvements in animal production. Two clear examples where partnerships with industry and industry animal usage have been targeted in genomics research are the Atlantic Cod Genomics Broodstock Development Project and the Beef Genomics Initiative. Based on letters of support received from industry, as well as the interest voiced during workshops and other consultations, we are certain that ongoing industry-research partnerships will ensure further successes in genomics research. The intimate involvement of industry in the research through their animal populations represents a significant financial contribution as well as providing advantages in terms of priority setting, focus and relevance as well as improving the speed and quality of technology transfer.

**RC “Some of the vision appears to be ahead of its time. (e.g. [in humans] to find small genetic influences, scientists had to screen more than 1000 patients (and controls) for each disease for hundreds of thousands of SNPs. The next stage is perceived to be for cell biologists to work how the suspect genes do their damage – and for drug companies to develop appropriate medication. I am confused as to 1) whether ATAG really appreciate the scale of the undertaking and 2) how the information would be used – breeding programs or vaccine development as extremes”.**

The position paper sets out an ambitious vision – “Leading and Enhancing Canadian Animal Health and Productivity to 2025”. The Canadian animal genomics community recognizes the challenge that this represents, however, we are confident that the approach set out, together with the arrival of new technology platforms (e.g. the \$1000 genome), can deliver this vision. Animal populations offer a number of advantages for genomics research including the availability of sufficiently large numbers of pedigreed animals, the opportunity to measure complex traits and collect specific tissue samples, the potential for sophisticated treatment programs and of course the ability to design specific matings. It is anticipated that the information would be used in a number of different approaches from marker assisted selection and genome wide selection in breeding programs (see for example the lead provided by the dairy industry), marker assisted management, diagnostics and the development of improved vaccines. Ultimately these developments and applications will be determined through industry interaction informed by the results from GE<sup>3</sup>LS research on consumer acceptability and demand.

Made-in-Canada genomics tools and solutions to problems of our animal based industries are evolving at a tremendous pace. As stated by Jacques Chesnais of the Semex Alliance, “The progress made in the last 12 months would have been regarded as science fiction last year.” The availability of tools for high throughput genotyping, including SNP platforms (e.g. the 50,000 SNP panel launched in 2008 by the Alberta Bovine Genome Program), are growing in Canada. A continued investment in genomics research will ensure that these new tools are maximally exploited to the benefit of Canadian animal production – both through breeding program enhancement and new tools development for managing animal health.

#### **RC -“The GE<sup>3</sup>LS issues must not be neglected”**

We believe that Canada has developed a leadership role in the area of GE<sup>3</sup>LS. We have taken care to demonstrate integration of GE<sup>3</sup>LS objective within the overall strategic research areas of the position paper. For this theme it is critical to understand the ethical, environmental, economic, legal and social implications of potential approaches to and outputs from animal genomics research. We demonstrate the very important and novel GE<sup>3</sup>LS research opportunities that focus on economics, animal welfare, and rural and aboriginal community impacts relating to increase profitability in agriculture and aquaculture. This theme will draw upon the internationally recognized Canadian GE<sup>3</sup>LS community to develop both integrated and stand-alone GE<sup>3</sup>LS projects that are relevant to the science of animal genomics.

#### **Summary**

The team felt that the 2007 review provided excellent guidance on how to improve the Position Paper. The feedback from the reviewers was used to focus the 2008 ATAG Workshop (Ottawa, May 29<sup>th</sup> 2008). This approach stimulated much discussion. For instance the animal welfare, animal worker safety, rural economy, and wildlife interactions and benefits were included. We also brought in three international speakers who provided a view from the outside and spoke to “What should Canada do in Animal Genomics that is unique and world leading.” This also promoted new insights and led the participants to look again at international partnerships to strengthen our paper. Finally, in the afternoon we focused on a “WOW” statement. This statement is something simply stated and easily understood so that anyone can understand our overall goal: The “25% increase in production by 2025” was the result.

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- <sup>xxxvi</sup> <http://gels.ethics.ubc.ca:8213/ge3ls-arch/animal-welfare>; <http://codgene.ca/investigators.php>; <http://gels.ethics.ubc.ca:8213/collaborative-projects/cgrasp>
- <sup>xxxvii</sup> <http://web.uvic.ca/csrs/research/gels.php>
- <sup>xxxviii</sup> See for examples: [http://ec.europa.eu/research/biotechnology/ec-us/docs/ec-us\\_workshop\\_animal\\_genomics\\_july\\_2006\\_en.pdf](http://ec.europa.eu/research/biotechnology/ec-us/docs/ec-us_workshop_animal_genomics_july_2006_en.pdf); Green, R.D. et al. 2007. Int. J. Biol. Sci. 3: 185-191; [http://www.bbsrc.ac.uk/about/pub/reports/FAGR\\_11\\_10\\_05.html](http://www.bbsrc.ac.uk/about/pub/reports/FAGR_11_10_05.html); <http://www.ars.usda.gov/research/programs.htm>.