Genomics and Agri-Food Sector Strategy (Livestock) Workshop

In association with: Genome Alberta, Genome Canada, AAF, AAFC and NSERC

Canadian Beef Breeds Council Technical Forum

In association with: Genome Alberta, Genome Canada, AAF and CIBC

BMO Conference Centre, Stampede Park, Calgary, Alberta




2017 AUG 15

Summary Report

Genome Canada is collaborating with regional genome centres (6) and other departments and agencies to consult with a broad range of stakeholders (input welcome until November 30, 2017) to update and refresh "The Opportunity for Agri-Food and Genomics in Canada" 2013 Sector Strategy document (March 2018). As part of this national effort, a one-day workshop featuring presentations from distinguished scientists and industry leaders, complemented by facilitated discussions, was held in Calgary on August 15, 2017. This report comprises four sections: 'Acronyms', 'Workshop Agenda', 'Key Takeaways' and, for each presentation, 'Workshop Summary Notes'.

To help address, "what does the Canadian livestock industry need, short-term and long-term, and how can the genomics community best contribute and lead?", snowflake icons appear next to key sector challenges and opportunities with possible genomics-enabled solutions, which are further distinguished in a different font colour.

ACRONYMS

AAA	American Angus Association	GM(O)	Genetically Modified (Organism)
AAFC	Agriculture and Agri-Food Canada	h2	heritability
AGI	Angus Genetics Inc.	K	thousand
AMR	Anti-Microbial Resistance	M	million
BCM	bromochloromethane	MAM	Marker-Assisted Management
BLUP	Best Linear Unbiased Prediction	MBV	Molecular Breeding Value
BOLT	Biometric Open Language Tools	MLF	Maple Leaf Foods
CAA	Canadian Angus Association	NAE	No Antibiotics Ever
CBBC	Canadian Beef Breeds Council	NB	New Brunswick
CCA	Canadian Charolais Association	NCE	National Cattle Evaluations
CDN	Canadian Dairy Network	NL	Newfoundland & Labrador
CFIA	Canadian Food Inspection Agency	NSERC	Natural Sciences and Engineering Research Council
CMC	Canadian Meat Council	OIE	World Organization for Animal Health
CPC	Canadian Pork Council	ON	Ontario
CPI	Canadian Pork International	PEDv	Porcine Epidemic Diarrhea Virus
CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats	PRRSV	Porcine reproductive and respiratory syndrome virus
d	day	R&D	Research & Development
DIVA	Differentiate Infected from Vaccinated Animals	RFI	Residual Feed Intake
DNA	DeoxyriboNucleic Acid	RWA	Raised Without Antibiotics
EBV	Estimated Breeding Value	SCID	Severe Combined Immunodeficiency
EPD	Expected Progeny Difference	SIP	Swine Innovation Porc
ERT	Economically Relevant Traits	SNP	Single Nucleotide Polymorphism
FAANF	Functional Annotation of Animal Genomes	ssGBLUP	single-step genomic BLUP
FAO	Food and Agriculture Organization (of the United Nations)	t	tonne
FC	Food Conversion	TAC	Technology Access Centre (Olds College)
FDA	(United States) Food and Drug Administration	U of A	University of Alberta
GDP	Gross Domestic Product	U of G	University of Guelph
GE-EPD	Genomic-Enhanced Expected Progeny Differences	U of GA	University of Georgia
GE3LS	Genomics and its Ethical, Environmental, Economic, Legal and Social aspects	US MARC	United States Meat Animal Research Center
GGP-LD/HD	Geneseek® Genomic Profile- Low Density / High Density	USA	United States of America
GHG	GreenHouse Gas	VIDO	Vaccine and Infectious Disease Organization

WORKSHOP AGENDA

Genomics and Agri-Food Sector Strategy (Livestock) Workshop

07:45	**Coffee and Registration**
08:15	**Welcome, Introduction and Opening Comments** – David Bailey, Jeff Stewart & Gordon Neish
08:30	**Genomics tools usage in regulation (CFIA)** – Alfonso Clavijo, CFIA
08:40	**Industry challenges & Genomic opportunities to meet future market demands** – Michael Young, Canada Pork International – Volker Gerdts, University of Saskatchewan
09:10	**Swine Genomics - current and future trends** – Graham Plastow, University of Alberta
09:25	**Discussion on Genomic Solutions for Swine Sector** – Facilitator: John Ross (CPC)
10:00	**Health Break**
10:15	**What do Canadian dairy producers need to compete in the marketplace?** – Elise Gosselin, Novalait
10:30	**Dairy Genomics – current status and future trends** – Craig Leroy, EastGen and dairy producer
10:45	**Fertility, production and milk composition to meet future market demands** – Christine Baes, University of Guelph
11:00	**Discussion on genomic solutions for dairy sector** – Facilitator: Brian van Doormaal, Canadian Dairy Network (CDN)
11:45	**Poultry genomics – what is currently happening and what should Canadians be supporting?** – Mitch Abrahamsen
12:00	**Lunch**

Canadian Beef Breeds Council Technical Forum

12:30	**Welcome and Opening Comments** – Genome Alberta, Alberta Agriculture, CBBC
12:45	**Gut and rumen microbiome – the 3rd factor in understanding animal health and performance** – Tim McAllister, AAFC
13:00	**Recent Advances and Applications in Animal Breeding and Genetics** – Matt Spangler, University of Nebraska
13:40	**Breeding and Genetics: Producer Focus** – Lance Leachman, Big Gully Farm
14:15	**Genomics tools and services** – Michelle Miller, Delta Genomics
14:35	**Health Break**
14:55	**Genetic Evaluation: now and in 2027** – Dan Moser, Angus Genetics Inc.
15:40	**Panel Discussion/Open Forum** – Facilitator: Jay Cross, University of Calgary
16:30	**Close**

KEY TAKEAWAYS

COLLABORATION and FUNDING ENVIRONMENT

Agencies and organizations recognize the value of genomics and want to be part of (and contribute to) a national strategy.

Further serve and advance innovation science and regulatory science in Canada by designing a more organized, collaborative and focused funding environment.

DEEP PHENOTYPING – Precision Livestock Agriculture

Better understanding of the biology of an animal and how its performance is impacted by (and can be improved in) different environments by collecting a great deal of precise data and targeted samples to refine understanding of genetic control elements (FAANG approach) and ensuring the bioinformatics capacity and a more uniform data management system (across species) to properly interpret the data that exist. Commercial crossbred data could be used to inform selection decisions in pedigree populations. Additional emphasis on collecting information related to feeding behavior, temperament and stress and pain assessment can modulate animal biology and influence overall health and productivity.

EDUCATION, KNOWLEDGE TRANSFER and SOCIAL ACCEPTANCE

Educate young students and their teachers about new technologies as an important first step in social acceptance.

Improve end-user adoption rates of new technologies by better communicating information (not just data).

Enhance efforts to gain social acceptance of technology by communicating trade-offs early and promoting success stories on social media.

ENVIRONMENTAL SUSTAINABILITY

Continue vital research to reduce the carbon footprint of the livestock industries through genomics-enabled technologies.

HEALTH

Develop accurate, rapid and cost-efficient diagnostic tests for important livestock diseases and gain an improved understanding of animal biology, microbiomes and the immune system, which will lead to increased disease resilience, better management, effective vaccines and the responsible use of antibiotics. Animal welfare is a huge part of the link between stress and health – thus the need to develop better management practices that are welfare friendly and reduce stress.

PRODUCT QUALITY

In every sector, exploit opportunities to improve agri-food processes and product quality through genomics.

WORKSHOP SUMMARY NOTES
Genomics and Agri-Food Sector Strategy (Livestock) Workshop

08:15 **Welcome, Introduction and Opening Comments**

David Bailey, Jeff Stewart & Gordon Neish

- Introductory comments and Introductions

08:30 **Genomics tools usage in regulation (CFIA)**

Alfonso Clavijo, CFIA

- CFIA role is to safeguard Canada's food supply and protect animal and plant health, and genomics plays an important role. CFIA has increased its genomics capacity in recent years (infrastructure, people, partnerships).
- Primary activities are conducted via CFIA's Lab Science Network, which is part of OIE that sets international standards for animal and veterinary public health. OIE also serves as the scientific reference body for international trade of animals and animal derived products.
- Genomics enhances precision and robustness of testing, decision-making and regulatory approaches, and is in line with the international trend to use genomics-based technologies to underpin standards and facilitate trade.
- Going-Forward Strategy: (1) develop platforms to streamline testing for important livestock diseases, (2) validate these platforms for national and international use, (3) engage with OIE to encourage large-scale adoption of newly developed platforms.
- Collaboration is key to advancing innovation science and regulatory science and CFIA looks forward to working with multiple business partners (e.g. Genome Alberta, Genome Canada).

Q: When will pathogen database be available to researchers?
A: Most work relates to infectious diseases; discussion is underway but date hasn't been set.

Q: Is there a list of priority diseases and, if so, can we see it today?
A: The list exists but a copy isn't available for presentation today. [see update below*].

Q: What exactly is CFIA research capacity (people) today? Please include facts in summary report.
A: No exact answer -- there is a community of workers across labs. Winnipeg has one scientist and two bioinformatics experts in genomics and Lethbridge will soon hire someone. As mentioned, collaboration with Universities is key. No single organization can tackle all.

Q: How easy or difficult will it be to get OIE to adopt newly developed platforms? Is Canada ahead of the curve and helping to set standards in OIE?
A: OIE comprises 150+ countries and so it is never an easy task. Canada is at par with what is accepted in the USA. Much of this relates to export. If the CFIA has an acceptable tool but is trading with a country that doesn't accept genomics tests, then the CFIA will work with them to develop projects to help convince them of its value.

***USING GENOMICS TO ADVANCE ANIMAL HELATH AND TRADE – CANADIAN FOOD INSPECTION AGENCY (CFIA) PRIORITIES IN GENOMICS**

Through the adoption of innovative genomic methods, the CFIA will continue to meet its obligations to international standard setting bodies, and thereby result in the international support of trade and market access for Canadian products. Genomics technologies are already making a difference at the Agency by providing knowledge to support more efficient and effective decision-making practices. The main areas of interest to CFIA are:

1. Development of new technologies and methodologies to keep pace with pathogen evolution and reduce the time and costs associated with the surveillance, detection, isolation, identification and characterization of high priority, emerging and unknown/unexpected pathogens. This includes new tests that provide unsurpassed accuracy, sensitivity and specificity, high throughput of samples, including field deployable tests. By developing these tests the CFIA will protect the agricultural infrastructure by adding value to all three stages of an outbreak of a foreign animal disease: early detection, response and recovery. These genomic-based tests can also be used to allow movement of animals during an outbreak or recovery period.
2. Development of new tests and analysis methods for comprehensive hazard characterization (pathogen profiling, etc., anticipating potential outbreaks or incursions). These tests will enhance Canada's capacity to resolve animal health trade restrictions by clearly identifying the origin or the strain involved in an animal health incident.
3. New technologies for fully automated multi-pathogen detection. New user-friendly multiplexing technologies will allow the reduction of cost and time for animal testing to fulfill import and/or export requirement and enhance Canada's position to access international markets.
4. Data storage and bioinformatics tools/pipelines for the rapid and automated analysis of external and in-house generated Next Generation Sequencing data for Animal Health. Next generation sequencing data mining will allow CFIA to identify genetic changes that continuously occur in the field in Canada and globally to maintain effectiveness of diagnostic tests, identify the earliest genetic/biomarkers of infection, and differentiate bacterial or viral status of an animal population, opening commercial opportunities and generating critical information for disease surveillance and control. At the same time, providing in-depth real time information during animal health emergencies.
5. Top priority pathogens for CFIA include tuberculosis, Brucella, foot-and-mouth disease, classical swine fever, and highly pathogenic avian influenza which are used to demonstrate Canada's freedom from these diseases as well as animal pathogens testing for export certification.

8:40 **Industry challenges & Genomic opportunities to meet future market demands**

Michael Young, CPI

- CPI (est. 1991) is a joint initiative of CPC and CMC; it is the export and domestic development and promotion agency of Canadian pork industry (12,000 producers, 19 processing plants, 20 trading house) and has offices in Canada (3), Japan (1) and China (1).
- Trends in production and exports (67% of total produced: 1.2M tonnes valued at $3.8B in 2016) continue to climb. Top markets include Canada (~750K t), USA (~400K t), China (~300K t), Japan (~200K t), Mexico (~100K t), of which Japan is the highest value market (28%).
- Fresh (chilled) pork exports are the hardest markets to operate in (vs. frozen pork) but more lucrative and Canada has seen an exponential increase in fresh (chilled) pork exports to Japan in last the 10 years (taking market share from USA).
- Global pork exporters (competitors) usually cater to very different markets however, in recent years, Canada has seen increased competition from Germany and Spain, who are vying for the same markets.
- Pork quality is a function of both on-farm and in-plant factors and the definition of 'ideal' depends on the customer (further processor, retail end-user, food service end-user). Also, pork grading systems can vary greatly between countries (examples cited: Canada, USA, Japan, Korea, European Union). Genomics plays a big role in optimizing pork quality.

Volker Gerdts, University of Saskatchewan

- From VIDO and will present a researcher's perspective on genomic opportunities to meet future market demands.
- Identified 3 opportunity areas: Performance, Health and Value-added (consumer trust) but will focus on health – next generation vaccines are much more advanced (can distinguish between infected vs. inoculated, which is important for trade) but need faster diagnostics (< 2 hrs).
- 2016 gene editing success story: knocked out one of receptors (CD 163) for PRRSV. These pigs cannot be infected with PRRSV.
- Improve disease resistance through a better understanding of immune system under production environments:
    - Gain a better understanding of the immune system studying SCID pigs (recall 'bubble boy'), which have virtually no B or T lymphocytes and are completely immune compromised.
    - Investigate link between innate immunity (response measured in minutes, not days), now called 'host defense molecules', and the microbiota. Neonatal pigs fail to make pBD-1 in lungs (host defense peptide that is a major component of innate immunity), which makes them more susceptible to respiratory infections (aside: expression of pBD-1 occurs in older piglets and confers increased protection). One (1) gram of pBD-1 can kill 100M bacteria in less than a minute (!) – very potent and synthetic pBD-1 is now being used in vaccines.
- Genomics in Vaccine Research: subunit vaccines, live-attenuated vaccines, DIVA vaccines – the FUTURE (e.g. used in Europe to control pseudorabies), infectious clones (e.g. PEDv infectious clone) – once created, it is possible to alter or mark them (for trade), reverse vaccinology (sequence pathogen genome to predict epitope (part of antigen molecule to which antibody attaches) and come up with a list of potential candidates and ascertain which ones give protection).

9:10 **Swine Genomics - current and future trends**

Graham Plastow, U of A

- Canada provides the world with genetic improvement (thanks, in part, to high health status) and it is one reason the pig industry thrives here.
- "We've done all the easy things": made huge improvements in last 50 years (78% less land, 41% less water, 35% smaller carbon footprint per unit of pork); carcass has improved dramatically; can now sequence the entire genome for ~ $1000.
- Summary slide from Ensembl lists 20,000+ coding genes (many more SNPs, which are easy to find in coding genes). What isn't so easy: the rest of the sequence that isn't coding (e.g. finding out what gene is switched on in the lung but not in the gut is a tougher question). FAANG is helping.
- SIP research priorities 2018-2023: responsible use of antibiotics, improving pig health, reducing feed costs and improving feed efficiency, pig reproduction, environmental sustainability, industry sustainability and competitiveness, international marketing of Canadian pork, Consumer diet and health, Animal welfare and behavior.
- Believes health (more precisely: "Disease Resilience") is one of the biggest opportunities for animal genomics. 2016 UK review predicts that if AMR isn't tackled now, by 2050 one person will die every three seconds!
- Improving Disease Resilience is the way forward but it won't be easy and will require 'deep' phenotyping (precision measurement); techniques and tools used in longitudinal studies on humans could be used in animal studies (e.g. Precision Livestock Agriculture).
- A vision for Precision Livestock Agriculture would include omics profiling (genome, transcriptome, proteome, metabolome, microbiome), phenomics (area of biology concerned with measurement of phenomes (= set of physical and biochemical traits of an organism) as they change in response to genetic mutation and environmental influences) using automated data collection (e.g, wearables) and the use of biomarkers to ascertain how animals changed over time, how they respond to different environments, feeding programs, stress (assessment) or disease and how the different omes interact.
- "GM pigs take step to being organ donors" – so much potential for genomics it's important that we don't repeat the mistakes made when GM was first introduced.
- What is the right path forward? FAANG approach appeals: Genome to Phenome, Enabling Precision Livestock Agriculture, Better Selection for Our Priorities, Informing Genome Editing.

9:25 **Discussion on Genomic Solutions for Swine Sector**

Facilitator: John Ross (CPI)

- CPI view of the world: "I have to sell pork to people who aren't happy about GMO", "PRRSV resistant pigs can't be sold (considered a scientific curiosity)"
  - Should Genome Canada spend time on that?
  - Suggestion is that PRRSV resistant pigs can't be sold because packers are concerned about consumer response to vaccines. It should also be noted that it's a relatively new discovery and there is no regulatory framework in place (5 – 10 years?), which means there's time to help solve regulatory issues.
- Graham Plastow asked to expand on "mistakes made regarding GMO": Forcing technology on consumers is not the way to go and we need a wiser approach.
  - Recently, salmon industry boasted it had GMO stock but they would not be distinguished from non-GMO. Bad idea.

  - There's a need and opportunity to educate youth (in the classroom) AND their teachers.
  - Sensible to continue with GE^{3}LS piece (as part of research) and communicate trade-offs (what it does and doesn't do) to public. Start early (before product is available for sale), ideally while research is underway.
  - Consider anti-vaccine debates – an emotional issue (GE^{3}LS is about science, not emotion) and so we need to be ahead of the game. Use social media to promote and propagate new of success stories when they happen (e.g. recently, a human fetus was helped with CRISPR technology (article)). Focus on how best to explain and introduce the topic.
  - Agree that socio-economic piece is important but we must remember that we are an exporting nation and that one piece must be part of an industry that is profitable (to ensure sustainability).
  - Most agree that the socioeconomic acceptance of technology needs to be a higher priority and Genome Canada must be mindful of that fact.
- What is the balance between funding research to develop tools that would be very useful but may not be accepted? (e.g. Enviropig 'disaster')
  - Not sure Enviropig was a complete 'disaster' – knowledge was gained and it may be unreasonable to expect immediate consumer acceptance (research to application is very fast in today's world). About that GMO salmon… the fact that it is being sold is noteworthy (and a sign of progress).
  - Enviropig –that was a perfect opportunity to have done it right, to get the public to support it; let's seize this opportunity, work together and get Canada ready for the technology; science piece + social piece = success.
  - RWA is gaining momentum – Canada is one of the biggest suppliers (MLF especially). Now Japan is expressing interest and "it's unlikely any amount of communication will bury it (RWA)".

10:00 **Health Break**

10:15 **What do Canadian dairy producers need to compete in the marketplace?**

Elise Gosselin, Novalait

- Novalait: a research catalyst developing solutions and expertise for an innovative dairy industry ($6.17B in farm receipts (82% farms in Ontario and Quebec); $17.7B in processing sales (29% fluid, 71% industrial))
- Business model: for every 100 litre sold, $1.27 is collected by Novalait (~$750M per year)
- Since 1995: $45M research portfolio (100 projects), 2 NSERC strategic networks, 6 NSERC industrial chairs.
- Genomics already applied to cheese making and ripening: rapid pathogen ID, microflora activity, real-time quality control. More genomic solutions: Searching the microflora of local milks & cheeses, systems biology applied to cheddar productions, improving the history of health and fertility traits in dairy cows, markers associated with epigenetic and metabolic status of embryos
- Genomics opportunities:
  1. Profitability
     - Producer survey: (a) production (b) reproduction (c) milk composition (↑ milk fat, ↑ milk protein (casein) (d) monitoring -- rely on cheesemaker's nose so need a 'genomic nose'.
  2. Consumer Benefits
     - Consumers looking for authenticity, flavor, diversity. Cultures provided by only a few companies in the world and so Canada's distinctive cheeses rely on: ecology of milk's native cultures, metabolic pathway of flavour.
  3. Environment & Sustainability
     - Reduce carbon footprint of dairy products (↓ GHG, ↑ productivity, ↑ food efficiency, better manure & soil management).

4. Regulatory Support & Diagnosis
    - Food safety, animal health – accurate, rapid, cost efficient
- Dairy industry wants to be part of a national genomics strategy -- it has rapid integration of genomic solutions, world class researchers and research funds!

10:30 **Dairy Genomics – current status and future trends**

Craig Leroy, EastGen and dairy producer

- Brief Bio: from dairy operation (robotic facility) in ON, U of G grad, Eastgen Dairy Specialist (ON, NL)
- Genomics used by: top herds, herds with little data, interested producers, progressive operations
- Genomic testing uptake by province: most < 10%, NL and NB much higher.
- Why higher in NL? Funding, shortage of feed and space, little market growth, less data
- Reasons for not using genomics testing? Cost, time / labour, shortage of heifers (if using all, why test?), tradition of "let a cow prove herself", lack of knowledge about application
- Reasons why farmers are interested: Maximize genetic progress, confidence in culling decisions, reduce risks, raise fewer heifers, most milk per stall
- What builds confidence in genomics testing? When (high indexing) animal moves to 'Proven' category
- Sire genetic progress: noticeable uptick in 2009 when genomic selection adopted in earnest
- Compare LPI (lifetime Profit Index) vs. 305 ME (Mature Equivalents) – positive linear trend but outliers confound (bottom 30% LPI but top 305ME… could genomics help with that?)
- Concerns (re: use of genomics): market value of low end offspring, ownership of data
- Health & Fertility: avoid (undesirable) haplotypes, ↓ inbreeding, future test for ↑ immunity
- Suggested Keys for Future Genomic Usage:
    - Changes: ↓ growth, ↑ sexed semen quality, ↑ immune response, tighter margins
    - Funding/Cost (of genomic testing): ↓ cost, clear demonstration of value, low labour inputs
    - Producer Mindset: educate next generation, demonstrate cost of raising cattle to production age (can be offset using genomics), feature herds that use technology (testimonials help)

10:45 **Fertility, production and milk composition to meet future market demands**

Christine Baes, U of G

- Canadian Dairy Industry:
    - Farms: 11,280 Farms, 1.4M cows & heifers, $6.17B farm receipts
    - Trade: Dairy products ($969M imports, $235M exports), Dairy genetics ($155M exports)
- DairyGen Council invested $20.7M ($7M industry, $13.6M Gov.) in genetic improvement since 2000
- Net Benefit ($) per cow per year: before $84, with genomics $171 $_{2009\text{-}2014}$ $237 $_{2015\text{-}2019\ (projected)}$
- DairyGen Council Priorities:
    - reproduction: ↑ fertility phenotypes
    - health: mastitis resistance, metabolic disease, hoof health, fertility disorders, immune response, resilience to environmental stressors, animal welfare (i.e. stress, lameness)
    - efficiency: ↑ feed efficiency and ↓ emissions, ↑ breeding efficiency
    - milk: composition, technological and sensory properties
    - breeding (↑ accuracy of predictions): incorporate novel technologies into animal breeding (address concerns re: inbreeding)

  - methodology: 10,000 Cow Genomes Project (access to 2M globally), New methods (single-step evaluations), Novel methods for accurate estimation of inbreeding / diversity, Methods to account for EBV underestimate due to pre-selection
- Enhance Profitability through Genomics: Environment and Climate Change, Global Competitiveness, Human Health and Nutrition, Food Security and Food Safety

11:00 **Discussion on genomic solutions for dairy sector**

Facilitator: Brian van Doormaal, CDN

- Brief slide presentation as prelude to discussion:
  - Important to remember there really is only one product: The Dairy Product, whether it is from the animal (e.g. milk) or the animal itself (e.g. meat), it's all just about one animal, with one biology and so we must focus on the animal's ability to produce product.
  - Dairy Cattle Selection
    - Quantitative: historically, focused on increasing lifetime production but, in last 15 years, that has shifted to ↓ costs of production and ↑ efficiency
    - Qualitative (e.g. milk composition): selected for overall fat and protein in milk; payment systems have never rewarded specific fat or protein levels (e.g. kappa casein for cheese). Possible to select for specific fatty acids but how will it affect milk (heart healthy or not?)
    - New Technologies: Genomics works – dairy industry is proof (all males have proofs!). Technologies like gene editing offer opportunities (e.g. polled gene, fertility haplotypes) but care is needed regarding consumer perception.
    - Discussion questions:
      (1) R&D infrastructure
        - Optimum investment balance: fundamental research vs. commercial application?
        - Infrastructure needed? Changes to organizations and funding mechanisms?
      (2) How best target dairy genomics research to ↑ GDP, food security and export?
      (3) Best opportunities re: beneficial microorganisms in processing (e.g. yogurt, cheese,)?
- What is infrastructure in dairy – what's missing? Consider beef cattle (already lots of data on methane)
- Only 80 Canadian Dairy bulls with sequence data – need more genotypes and phenotypes.
- About funding:
  - Funders need to be better organized and collaborative (researchers are leading by example). Right now, all funding groups are updating their strategies in anticipation of the next round of funding.
  - International collaboration: Pro (adds research capacity missing in Canada), Con (could impact competitiveness and Canada is an exporter)
- Return to earlier conversation about GMOs: Don't be faint of heart – it's a long game. In 30 years the technologies will be accepted. Biggest mistake with InVigor? Getting farmers to buy in without consumer.
- Concerns about inbreeding? Yes – in dairy, balance rate of change and rate of inbreeding. Unlikely to see crossbreeding in dairy sector, more likely strategy is to develop separate lines (genetically distant) and occasionally cross lines to reduce inbreeding.
  - Mitch Abrahamsen later added: Why so worried about inbreeding when you have the tools to measure it and it's never happened? In the broiler industry, lines have been closed for 50 years and inbreeding isn't an issue. As long as you can monitor inbreeding at population level (and correct situation, if needed), then there's no need to worry about it.
- CDN has executed its strategy – what's the glue that keeps the network successful? (1) Umbrella organization that represents all stakeholders (all involved in setting research priorities = focus) (2)

Successful funding model that was specified from outset (in some cases (e.g. milk recording), there is no actual money transfer -- their services are valued and, in turn, they receive the support needed to operate)

11:45 **Poultry genomics – what is currently happening and what should Canadians be supporting?**
Mitch Abrahamsen

- Key messages: More data (DNA genotypes) is better, "phenotypes are king" and genomic selection works!
- How to feed the world? Poultry is well positioned.
- World is changing: now there are only 2 suppliers of poultry breeding stock worldwide
  - What if one messes up? The two suppliers really need to work together.
  - Responsibilities: Food security, Environmentally friendly, Economically viable, Socially acceptable
  - Innovation means fewer birds (32B fewer in 2050) can produce the same amount of product.
  - Balanced selection includes: FC, Growth rate, Meat Yield, Leg Health, Livability, Heart & Lung health, Egg production and hatch – almost all traits measured on pedigree farm and ½ are geared toward health and welfare improvement.
- Sustainability in a changing world – activists cannot be ignored (ability for consumer to pressure McDonald's, who in turn pressures Tyson Foods is astounding).
- FAO estimates 855M broilers needed in 2050 (450M in 2016)
  - Challenge: decrease in arable land and available water (climate change)
  - Challenge: use of antibiotics (and AMR); recent headlines include "FDA Issues New Regulations on Antibiotic Use in Livestock", "Perdue Foods says its chicken hatcheries now antibiotic-free", "Cargill Turkey says 'NO' to growth-promoting antibiotics" and there's even a movement towards NAE
  - Challenge: social acceptance ("Nestle announces groundbreaking global animal welfare reforms", "The Chicken Tax: Maryland's New 'RAIN TAX' (polluters 'pay fair share' to clean up Chesapeake Bay) – bill failed but believe it's 'tip of the iceberg')
- Disinformation abounds…
  - "80% of all antibiotics are used on factory farms" UNTRUE (but many people remember it)
  - "Slow Growing (chickens) – The 'next best thing'" UNTRUE (but many people believe it)
  - Seattle Organic Restaurants publishes UNTRUE claims about use of hormones. In truth, the only hormone ever used in raising chickens was outlawed by Congress in the late 1950s.
  - "Meat and dairy products are a major cause of climate change…" UNTRUE
- New Selection Paradigm
  - Pedigree farms are sacred - use 4-way cross and birds go around world in only 2-3 'pipelines'; genetic lag ~ 4 years. Commercial birds perform in all environments (some very well, others not). Aside: 1 (pedigree) hen → 4M (commercial) offspring so identify right phenotypes.
  - Big Challenge: possible to 'back-engineer' system using data (DNA variants) on relevant commercial phenotypes to select "best" genotypes on pedigree farms? This would allow a quick response (entire system relies on genetics of only 30 to 40 (easily replaced) males)) to climate change, social concerns, etc. observed in commercial settings.
  - Genomic Selection (DNA is Data = Better) – most importantly, it would permit incorporation of new traits into breeding performance (e.g. if climate change is a concern, could investigate question in commercial birds currently raised in hot climates).
  - Possible new traits: (1) intestinal health (2) targeted disease challenge models (3) resilience (improved performance in sub-optimal conditions)

- Repeat key messages, adding: "it's not a genomics story anymore; genomics is just a tool – go back to phenotypes and physiology; train people to understand the biology of the animal they are working on."

Q: Given level of investment in private company, what do you think academic priorities should be?
A: phenotypes – understanding biology and what happens to biology in different environments.

12:00 **Lunch**

Canadian Beef Breeds Council Technical Forum

12:30 **Welcome and Opening Comments**
Genome Alberta, Alberta Agriculture CBBC

12:45 **Gut and rumen microbiome – the 3rd factor in understanding animal health and performance**
Tim McAllister, AAFC

- Human microbiome – so many organs and systems influenced by gut microbiome
- Steps: digesta sample, DNA/RNA extraction, sequence, bioinformatics analysis, tied to who/what/how
- Rumen microbiome (most complex) has bacteria, anaerobic fungi, ciliate protozoa, methanogenic archaea (4% - 12% of gross energy (GE) being released into atmosphere).
- Rumen microbiome is redundant, resilient and stable.
- Role of feed microbiome: microbes accelerate overall digestion; fermentation of crude protein results in production of biofilms (slimy layers of microorganisms that stick to wet surfaces).
- Factors that affect microbial community: result from variation in Subject (animal type, host specificity, diet, rumen phase, plane of nutrition, welfare and management) or Methodology (sample collection, sampling site, DNA isolation and analysis). Aside: rumen is a very structured community and different microbes inhabit different areas and so obtaining a representative sample is critical.
- Factors affecting animal species: variation in microbiomes is evident between continents (70% of bacteria have never been seen in lab) and the biggest factor influencing microbial composition was diet.
- Research trials
  - Looked at microbiomes of 9 species (elk, white tail deer, moose, bison, musk oxen, mule deer, beaver, porcupine, cattle) and their ability to digest fibre.
    - Similar bacterial diversity
    - Porcupine of special interest – can survive on stripped bark! CAZymes get credit --- possible to stimulate same enzyme production in cattle? What is best way to transfer microbes?
    - Fecal transfer in humans to combat C. Difficile has 90% success rate! Still, concerns about whether donor pathogens are being transferred.
    - A more refined approach of "rePOOPulating" the gut is MET-1 (ecosystem of pure microbes) has also proven successful.
  - Bison are more efficient at digesting fibre than cattle – would a transfer of rumen contents work?

        - In trial, replaced 70% of cow rumen contents with bison rumen contents and though the microbial population had clearly changed @ 28 d, there was no real difference in digestibility of fibre. Postulated that was because diets of cattle and bison are similar.
    - What next? Compare microbiomes of high and low feed efficient animals.
        - Beef cattle: some bacterial families were more abundant in cattle with poor feed efficiencies but archaea taxa were more abundant in efficient cattle.
        - Dairy cattle: To everyone's initial surprise, there were actually fewer types of bacteria in more feed-efficient cows. Perhaps it's because dairy cattle are raised in more standardized environments than beef cattle?
- What about rumen size? There's a direct effect of physiology on microbes – high feed efficient cattle had a larger rumen volume and digesta retention time.
  Aside: mice given penicillin at weaning were bigger and fatter as adults, and mice given penicillin-altered microbiota grew faster and were fatter too.
- Rumen development – Microbial colonization stabilizes in first 30 days. Wondered about a mother-child impact. Investigated mother-child impact in goats using BCM (treatment to reduce methane production): Animals treated with BCM produced less methane but treatment of does did not impact methane production in kids.
- Cattle given BCM showed a reduction in methane that persisted for 4 months (suggesting microbiome was altered)
- Research trials with goats suggest that colonization of microbiome begins in early life (possible it occurs pre-birth) and so contact with the mother (established microbiome) is important and we need to have a better understanding between stressful environments and the microbiome. A comparable example: Holsteins (weaned at an early age) moved into feedlots often have more problems with diseases (vs. beef cattle, which are weaned much later in life).
- Although this research has focused on rumen microbes, there are microbe populations throughout the gut that need to be researched (possible that programming rumen microbes impact microbes further in gut?)

13:00 **Recent Advances and Applications in Animal Breeding and Genetics**

Matt Spangler, University of Nebraska

- Tested animals for GE-EPDs Jan 2017: ~450K (68% Angus, 32% 12 other breeds)
- Two-steps: (1) Training (estimate SNP effects) (2) Calculate MBV using SNP effects → Fit MBV in NCE.
- Two "phenotype" choices for Training: EPD (regressed towards mean) or degressed EPD (include data from related individuals). Concern: using pedigree data in high heritability traits amounts to "double counting" (bias).
- Impact of SNP number (50K vs 80K)? negligible.
- Want to move away from blending (done post-evaluation) to single-step (ss) but there are considerations:
    - Weighting of markers: ssGBLUP (equal weighting) vs. ss'Hybrid' (weighted relative to importance); BOLT software package (computationally fast) can accommodate either.
    - Accuracy – a function of heritability (h^2) and no. progeny records. Also, genomic relationship matrices improve accuracy of EPDs because you no longer assume all grandparents contribute ¼ of their genes, you know exact proportion (range 0 to ½).
    - SNP Densities not static: 50K, HD770K, GGP-LD 50K, GGP-HD 77K, GGP-uHD 150K, … GGPF250 coming soon. Which test do you use and on which animals? Swine and poultry only test subset and impute genetics of near relatives, is that something for beef breeders to consider?
    - GGPF250: likely useful for across breed comparison (e.g. birth weight) and MAM
- Concerns:

  - Many producers never understood 'accuracy' and adding genomics isn't likely to help
  - Many ERTs not measured by seedstock producers but drive value downstream (reproduction, disease, carcass data, plant value). Commercial data matters!

- Commercial data matters:
  - Increase ERTs that have EPDs (e.g. input traits, fertility) -- potential of genomic selection will be fully realized when ERT data is collected
  - Benefits of multi-breed NCE: (1) inter-breed comparisons (2) ↑accuracy of 'composite' animals
- Across-breed comparisons
  - Across breed adjustments have been published for decades (but of limited use)
  - To estimate breed differences from field data, contemporary groups of purebred and crossbreds would be required (rare, plus would need good estimates of heterosis)
  - A challenge to correctly accommodate different models used by different breed associations
- "The global Animal Breeding and Genetics community has done a tremendous job… (but) despite these advancements, technology adoption is embarrassingly poor (<30% of producers use EPDs)"
  - Why? 'opaque' system, "less preferred" consultants advising, producers busy with day-to-day matters, combining partial solutions (breeding objective, breeding system, breed choice, trait emphasis, sire selection, …) is cumbersome
  - Proposed Fix (goal): a web-based decision support tool allowing producers to best choose replacement stock tied to their selection (economic) objectives (flowchart graphic included in presentation slides)

Q: Some of what you propose (commercial industry drives process) would require some major changes in organizations – do we have it backwards?

A: Believe answer is "yes". Look at the swine industry – the packers won. Though heresy to some, presenter would argue the essential function of a breed association is to serve the commercial industry (producing and selling an animal the commercial industry wants will be how purebred producers benefit).

Q: About crossbreeding – any incentive for organizations to open breed books?

A: Yes, for some traits, no one breed association has enough data. Also noted: idea of a 'breed' is an artificial and man-made construct (and the distinction becomes 'fuzzy' with genomics).

Comment: Dairy industry also trying to come up with web-based decision support tool (expected to greatly assist with adoption of genomics technologies).

13:40 **Breeding and Genetics: Producer Focus**

Lance Leachman, Big Gully Farm

- Big Gully Farm: Herefords (165 cows) in Saskatchewan. Sell bull calves and long-yearling bulls.
- Submit data for: calving ease, body weights, ultrasound (fat, lean), scrotal, udder score
- Test availability: 30K ($40), 70K ($75), Horned (pp) or Polled (PP or Pp) ($60), Freemartin ($75)
- At Big Gully: 70K (herd sires, donor dams, in-herd semen sires), 30K (sale bulls), suspect PP or Pp
- Timing of Samples: calves' tail hair @ birth or straw of sire semen – submitted 2 months before EPDs
- Opportunities: submit data on females (GE-EPD), blood test for freemartin status, 30K to 70K+, measure RFI, advance understanding and education

- EPD vs. GE-EPD: genomics data improved accuracy in low h^2 traits (Calving Ease) and greatly reduced number of 'progeny equivalents' (number needed to obtain same accuracy)→ Aids in decisions.
- Genomic testing benefits overlooked: ↑ pedigree integrity, ↑ credibility as progressive breeder, ↑ confidence in meeting customer demands, contribute to breed advancement and rate of genetic progress.
- Applications: cost/benefit, distinguish flushmates, distinguish service sire, identify future seedstock early
- GE-EPD advantage in 2016 bull sales: $828 more ($6,045 GE-EPD vs. $5,217 non-GE-EPD)

- Difficult to gauge cost/benefit of testing young bulls only, young heifers only, or both
- Summary Slide: main benefit of GE-EPD is increased accuracy of breeding values at a young age, genomic tests have beneficial practical applications, usefulness of GE-EPDs depends on trait, data collection (phenotypes) is critical, cost/benefit is a producer driven decision.

14:15 **Genomics tools and services**

Michelle Miller, Delta Genomics

- Current genomic landscape:

PANEL	Parentage	TECHNOLOGY
ISAG Core SNP Panel	EnVigour HX™ (parentage, genomic breed composition analysis (10 breeds), vigour score (% retained heterozygosity)	Agena Mass Array
Bovine LD (7K)	Impute to 50K for genetic evaluations, some genetic conditions, parentage	Illumina Bead Chips
GeneSeek GGP-LD (31K)	Genetic evaluations, parentage	Illumina Bead Chips
Bovine 50K	Impute to 50K for genetic evaluations, some genetic conditions, parentage, research tool	Illumina Bead Chips
GeneSeek GGP-uHD (130K)	Research tools, impute to 50K for genetic evaluations	Illumina Bead Chips
Bovine 777K & Bos1 Array (618K)	Parentage	Illumina Beads Chips & Affymetrix Arrays

- Upcoming genomic landscape:

50K PLATFORM	TECHNOLOGY	VALIDATED	GENETIC CONDITIONS
Bovine 50K	Illumina Bead Chip	YES	None
GeneSeek GGP-50K	Illumina Bead Chip	YES	Many
Affymetrix 52K	Affymetrix Array	In Progress	Yes*
AngusGS	News release was August 14, 2017		
Soon, cost of 50K genotyping will ↓1/3 (Affymetrix is competing for Illumina market share)			
All panels used by Canadian purebred beef industry must be: ISAG compliant parentage, accurate imputation to 50K for genetic evaluations, genetic condition markers			

- Diminishing landscape:

LD PLATFORM	PROS	CONS
Bovine LD (7K)	Available in Canada	Does not impute to 50K with high accuracy; no genetic condition markers
GeneSeek GGP-uLD (9K)	Imputes to 50K with >99% accuracy*; genetic condition markers	Not available in Canada; Long turnaround times
GeneSeek GGP-LD (31K)	Available in Canada; Imputes to 50K with >99% accuracy; genetic condition markers	Will be discontinued when GeneSeek GGP-50K is available in Canada

- Delta working with CBBC and breed associations towards seamless genetic evaluation for all pure breeds
- Beef Value Chain Genomics: Purebred (parentage, genetic testing, EPDs, Genomics & EPDs) → Cow/Calf (Parentage, Genetic Testing, EnVigour HX™), Feedlots (Genetic Testing, Leptin), Packer (non), Consumer (place demands on value chain)
- EnVigour HX™ Cost: $45 (order at DeltaGenomics) and soon available at Herdtrax, Olds College TAC. Benefits:
    - Parentage: $1800 per year to maintain a bull (make sure it's really the one you think it is)
    - Genomic Breed Composition: maximize breed complementarity, replacements costs ~$1250
    - Vigour score: a 10% ↑ in score ~ $6/head/year saving; $178/cow/year due to ↑fertility

Q: With regard to chip design, is the new reference genome being used?
A: Not certain and Canada doesn't have the volume of testing to justify a new chip.

14:35 **Health Break**

14:55 **Genetic Evaluation; now and in 2027 (Genomic Selection in US Angus; Now and in the Future)**
Dan Moser (AGI, a wholly owned subsidiary of AAA**)**

- AGI: 4 geneticists + 7 service representatives, plus strategic partnerships (U of GA,)
- Services: evaluations (weekly GE-EPDs since 2010) + service to 5 other breed organizations (CAA, CCA,)
- Key Topics: (1) History of Genomic Selection in US Angus, (2) Single Step Genomic Evaluation, (3) Future Areas of Interest
- GE-EPDs include information from Pedigree, Performance, Progeny Data, Genomic Testing.1st used Kachman model (complicated) but moved to Single Step genomic evaluation July 2017 (improved models for carcass traits, additional genotypes and data, updated h^2 and correlation estimates, updated $Values)
- Single Step Genomic Evaluation is better: captures variation in relationships, is a more direct model, is a more complete model (ultrasound images highly correlated to carcass; added weaning weight and fat); genetic trends are more stable.
- Single Step approach shown to be superior in US MARC validation and predicts performance better (confirmed in retrospective study). Also, approach rewards (weights) genotypes with supporting phenotype (bothered to collect data).
- Data + DNA Works! 363,000 US Angus genotypes and $/test continues to drop ($139, $75, $45, $37,)
- New for CAA: CAA data now part of AAA single-step genomic evaluations, monthly (~~semi-annual~~) runs
- AGI AngusGS Genomic Test: ↓cost, faster, 50K (core SNP 40K for single-step and >100 targeted genes)

Q: What are main differences between Canadian and USA Angus populations?
A: USA places more emphasis on birth weight and calving ease (market driven: sale of breeding heifers) and marbling, and is less concerned about inbreeding (so many independent decisions about breeding)

15:40 **Panel Discussion/Open Forum**
Facilitator: Jay Cross, University of Calgary

- Panelists (Tim McAllister, Matt Spangler, Lance Leachman, Michelle Miller, Dan Moser) assembled at front
- Four themes emerged:

(1) Incredible tools developed but adoption isn't universal – a concern? how do we improve that?
- What is state of field and what should the value proposition be? Huge investment in R&D but not always adopted. Part of problem lies with the appropriate sharing of costs downstream in the beef value chain (and yet Ireland has succeeded); Agreed – beef value chain is long and information isn't passed easily up or down the chain and it's a big problem. Also, research done on pens of cattle (variation in performance) but payment is on individual cattle. Of course, marketing on a grid or ownership would help.
- "We're good at generating information but not so good at translating it into knowledge" (people are paying for data but aren't sure how to use it). Adoption rate of genomics technologies is likely to increase if you provide knowledge/information (not just data).

(2) Data on traits we care about (fertility, carcass weight, FC,) is collected but EPDs are not generated for all traits across all breeds. Isn't that concerning?
- Some measurements (e.g. cow weight) are a real pain to collect but why not do it when they are in the chute (for vaccination).? Also, some novel traits like hair shedding (h^2 ~ 30%) are important in hot climates (Florida, Brazil).
- Only a few breeds have an EPD for mature cow weight. Growth to slaughter weight (increasing over the years) is important and can be estimated from yearling weights.
- What about feed efficiency (FC or RFI)? Hugely important (FC of 5.5 is average but it can range from 4 to 8) and yet a bull has never been sold on RFI – there's just not the financial incentive (feedlot doesn't reward cow-calf producer). Again, this topic of properly sharing costs (incurred to increase value of animal) up and down value chain emerges – clearly a different type of alignment is needed (e.g. shared ownership,). Not only that, we are also missing a NATIONAL beef improvement strategy (e.g. idea of moving commercial crossbred data into purebred EPDs would require a national approach).

(3) Idea that we should be collecting phenotypes to supplement genotypes
- Genomic selection in crossbreds – what is feasible? Collect data (simple, easy to measure) on a representative subset (don't need every record on every animal).

(4) Pace of improvement in other species is a challenge to the beef industry
- By 2050, there will be another 2.5B people – will beef production increase and, if so, how? Most believe increase is likely because, as people become more affluent, they'll demand higher value protein. Of course, there will be environmental pressures: how much potential does genomics have to reduce beef cattle emissions (not just methane)? Also, we need to educate the public or risk losing technologies (e.g. antibiotics, implants,).
- Time to mention the consumer – they value consistency, food safety and food security.
  - Not sure we'll ever see consistency in beef cattle industry
  - Canada has a national food policy and the first three points are plant-based!

Q: Last pearls of wisdom from panelists?
- Communicate information (not just data) up and down value chain, which includes consumers
- As geneticists, we make predictions about the future using imperfect models (forward looking)
- Be more aware of international competitors (e.g. Brazil) – we may not be able to compete on cost but our advantage lays in product quality.
- I don't see a soybean plant and a cow playing the same role in the system. All the forage you see – it's to feed cattle (part of grasslands culture).

16:30 **Close**