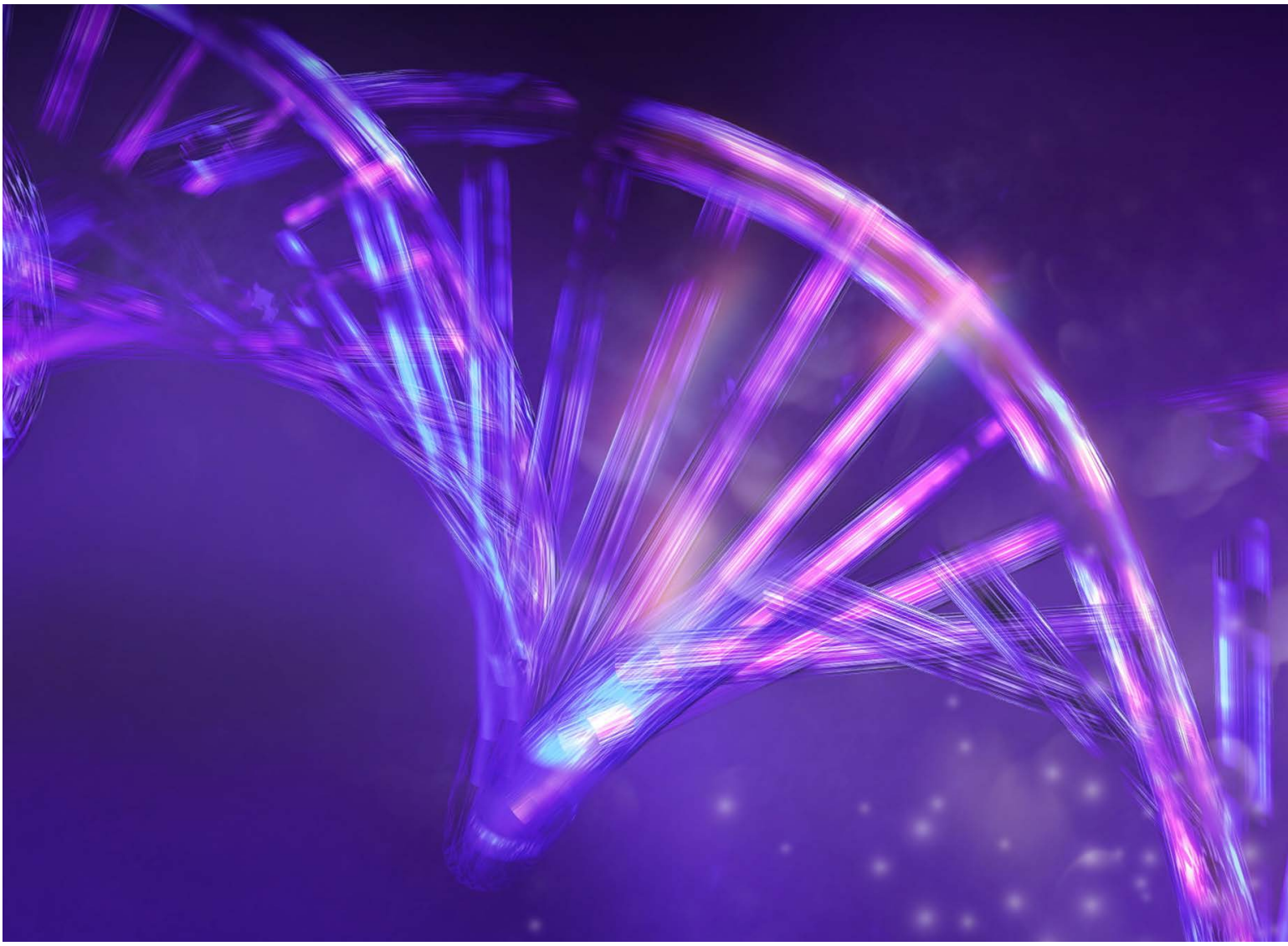
What We Heard

Pan-Canadian Genomics Strategy



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Executive summary

Budget 2021 announced an investment of $400 million for the design and implementation of a Pan-Canadian Genomics Strategy (PCGS) to advance the translation and commercialization of genomics and related technologies, strengthen Canada's global leadership, and position Canada for long-term success in the global bioeconomy. In May and June 2022, the Government of Canada conducted consultations with key stakeholders in the Canadian genomics ecosystem to better understand the challenges and opportunities associated with the commercialization and adoption of genomics. The primary objective of this engagement was to inform and refine the goals of the PCGS and gain insight into potential actions and interventions that could be deployed in priority areas.

The consultations underscored Canada's potential in genomics with existing strengths in genomics research. To realize this potential, respondents emphasized that the PCGS should take an ecosystem approach by establishing a clear, long-term vision for genomics in Canada. Within this ecosystem, cross-disciplinary priorities and strategic initiatives should be established to address specific genomics needs and hurdles across different sectors such as health, the environment/climate change, and agriculture/food security. To further innovation and commercialization of genomics technologies, increased collaboration amongst stakeholders and greater sharing of information across industry, academia, different levels of government, and other stakeholders is essential.

Other key findings specific to the PCGS themes included:

- Improving private sector and general public awareness of the benefits of genomics is key to advancing adoption of genomics technologies and innovations.
- Data management and sharing is critical to leveraging genomics within Canada. Common data standards, privacy regulations, cross-jurisdictional coordination, and developing storage capacity and analytical capabilities are needed to enable broad access to and use of data across the genomics ecosystem.
- There is a wide-spread need for increased funding, lab capacity, and access to infrastructure and equipment to support R&D and the commercialization of genomics technologies.
- The Government of Canada can help de-risk commercialization and private sector investment by adopting the role of first purchaser and supporter of novel genomics technologies.
- A specialized workforce is needed to translate genomics data into knowledge and intellectual property. Training in genomics, bioinformatics, and business/ entrepreneurship, as well as private sector awareness and capacity to employ genomics trainees, are essential to addressing talent gaps.
- Proactive measures must be taken to ensure equity, diversity, and inclusion (EDI) considerations do not contribute to talent gaps and instead positively impact training and hiring practices.
- Regulatory barriers must be addressed to accommodate techological innovation and facilitate the uptake and commercialization of genomics technologies.

Background

Genomics is the study of the genetic information of an organism encoded in DNA and other molecules, which includes the structure, function, evolution, mapping, and editing of genomes. Currently, genomics data sets are largely underexploited; however, there is an opportunity in combining genomics with big data, artificial intelligence (AI), gene editing and synthetic biology to extract additional value from data, the outcome of which may be used to drive economic growth, and respond to global and national challenges, such as climate change, implementation of precision health, pandemics, food and energy security. This potential is exemplified by the significant role that genomics and its applications played in helping Canada fight against the COVID-19 pandemic (e.g., variant tracking and sequencing, diagnostic devices, mRNA vaccines and therapeutics).

In recognition of Canada's strength in genomics research, Budget 2021 announced $400 million for the creation of a Pan-Canadian Genomics Strategy (PCGS) to advance the translation and commercialization of genomics and related technologies, strengthen Canada's global leadership and position Canada for long-term success in the global bioeconomy while enhancing coherence and coordination among the key players. The PCGS will consider the full suite of Government of Canada activities related to genomics, including investments in Genome Canada's new mission-driven approach and other PCGS-related initiatives across the genomics ecosystem.

Consultation process

To help refine the goals of the PCGS, the Government of Canada engaged with stakeholders in the Canadian genomics ecosystem to better understand the challenges and opportunities that exist on the path towards commercialization and adoption of genomics technologies, as well as solicit input on potential actions and interventions that could be considered in addressing identified priority areas.

In May and June 2022 ISED held a series of thematic roundtables with invited participants. Each roundtable focused on a specific element of the genomics ecosystem: talent, data, commercialization, adoption, as well as Canada's genomics landscape. An online public consultation was held in parallel during the same period.

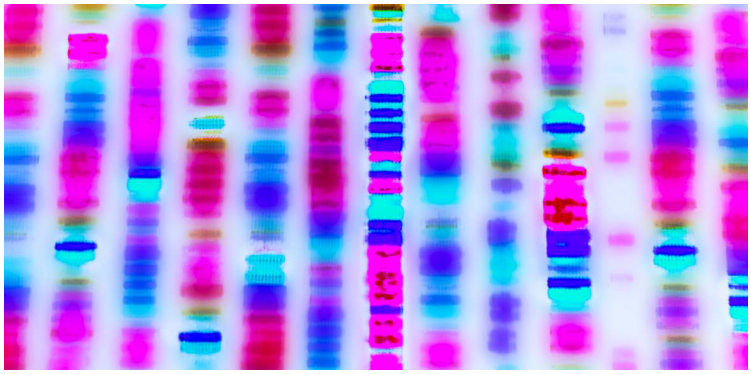
Overall, a total of 470 researchers, business leaders, and interested Canadians participated in the two consultation streams. This report summarizes stakeholder input gathered from the roundtables and online consultation.

Canada's genomics landscape

Canada's geography, regional biodiversity, and varied natural resources give Canada the opportunity to foster strengths across different sectors (e.g. agriculture in the Prairies, fisheries in Atlantic Canada, and health sciences in British Columbia, Quebec and Ontario). Should genomics innovation be further advanced and adopted, several key areas have the potential to deliver great economic and societal impact on Canada, including in:

- human health (e.g., via precision medicine, pandemic preparedness and response, drug discovery and production, and treatment of diseases and age-related illness);
- food security (e.g., crop yields, disease and pest monitoring, biomanufacturing of edible proteins, and tracking mislabelled or illegally obtained food products); and
- environment (e.g., improving the resilience of plants, animals and ecosystems in the face of climate change).

Canada's existing genomics landscape was generally characterized as having pockets of strength across all sectors. Participants highlighted the strengths of existing organizations, including



government facilities (e.g., National Microbiology Laboratory), and programming (e.g., Genomics R&D Initiative (GRDI)); the Global Alliance for Genomics and Health (GA4GH), to create data standards; and the Canada Foundation for Innovation (CFI) and the Digital Research Alliance of Canada (DRAC), to fund research and digital infrastructure. In addition, organizations such as Genome Canada and the regional Genome Centres were mentioned for their importance to support and fund regional projects and represent regional interests.

Canada's regionally diverse strengths were seen to present both challenges and opportunities. Participants commonly expressed that divisions based on regionality and jurisdictions

contribute to fragmentation across the ecosystem, where otherwise an integrated system could improve cohesion in the ecosystem and develop connections across sectors and between different stakeholders. Despite this fragmentation, regional strengths and capacities still need to be supported as they provide a natural focal point for building on existing capacity. Because of the regionality of genomics in Canada, regional interests and needs should help inform national priorities. As such, a national strategy should aim to support regional strengths while aiming to break down silos and improve coordination and collaboration across regions.

Participants' suggestions for advancing the genomics ecosystem in Canada included several elements:

- First, leadership is required to establish a national strategy with a clear vision, incorporating cross-disciplinary national priorities.
- Second, improved collaboration among stakeholders at all levels of government, industry and academia is critical to reducing fragmentation in the system. Collaboration could take many forms, such as sharing information, expertise and best practices, or through mechanisms that connect researchers and innovators with industry and potential receptors of new technology.
- Third, data standardization, to enable a federated data system is needed to improve interoperability and accessibility of data, whereas currently data is confined to institutional and discipline-specific repositories. A federated data ecosystem will help foster and facilitate collaboration as data could be more easily shared between different stakeholders.
- Fourth, training opportunities must be supported and increased to address talent shortages.
- Finally, success and growth is dependent on funding genomics innovation from research translation to late-stage commercialization.

Talent

The consultations consistently highlighted that a robust talent pipeline is a necessary component to advance the adoption and commercialization of genomics in Canada, and that training in genomics-related disciplines must be expanded. Three main priorities identified were the need to improve connections between talent and employers, improve multidisciplinary training, and address equity, diversity and inclusion (EDI).

There was general agreement that the trainees currently in the talent pipeline will not be sufficient to meet the anticipated need. As noted by many respondents, this is further complicated by the genomics sector having to compete not only with other areas of the bioeconomy and the technology sector for talent, but with other countries as well—many of which offer higher pay scales.

To address labour needs, it is important to build awareness of career opportunities in genomics amongst students while they are in the early stages of making decisions about their education and goals. Generating interest in STEM amongst high school students will be critical to developing a workforce that can support the genomics sector. As students progress through their education, applied training opportunities including internships, co-ops and collaborative research projects are key for helping talent to be industry-ready upon graduating. Participants cited Mitacs' work-integrated learning program as an example that could help support internships in the genomics sector. In addition, it was recommended that connections between academia and industry should be strengthened to help identify labour needs and shape training opportunities, as well as to support the successful transition of graduate students to the private sector. This will help retain talent with genomics-relevant skills as clearer connections are made between training and employment opportunities.

Multidisciplinary training and skills shortages were other interrelated issues identified. Skillsets such as data sciences (e.g., computer science, statistics, bioinformatics, artificial intelligence, etc.) and business and entrepreneurship (e.g., marketing, sales, commercialization, regulatory affairs, etc.) are important adjuncts to genomics and necessary for growing a thriving commercial sector; both were noted to be in short supply. To address these skills shortages, participants recommended expanding existing genomics training programs to incorporate multidisciplinary skillsets in their programming. Bioinformatics and data training were seen as especially important skills, to equip trainees with specific proficiencies needed across genomics, and these training opportunities would be enhanced by industry placements and collaboration.

There was also broad recognition that proactive steps must be taken to implement EDI in genomics. Targeted outreach, recruitment, and training for equity-deserving groups

will help address gaps in the candidate pool. This could be achieved by partnering with key organizations such as the Summer Internship for Indigenous Peoples in Genomics (SING) and scaling their program for greater national impact. In addition, it is important to engage with equity-deserving groups to better understand challenges and barriers faced in hiring and working conditions, and to collaborate with these groups to address and remove those barriers.

Data

Common data issues identified by participants were: the fragmentation of the data ecosystem, access to data, and data infrastructure. The sharing and accessibility of genomics and related data are essential for advancing knowledge, creating intellectual property, and catalyzing economic growth in relevant fields. However, in Canada, genomics data tends to reside in institutional and jurisdictional silos where the data standards and databases used to manage the data are not aligned and lack interoperability. This is particularly true for human health data, which is usually administered by provincial health systems, hospitals and labs, or other institutions – each with their own data management practices. To address these issues, national leadership is needed to encourage and facilitate collaboration between provincial/territorial entities and data generating institutions, and to promote an open data culture.

Many participants recommended a federated data framework to resolve the issue of fragmentation. A data governance approach, in compliance with international data standards established by standard-setting bodies such as the Global Alliance for Genomics and Health (GA4GH), would improve data sharing in health. GA4GH was frequently noted by participants for their international reputation in developing health data standards and was recommended as a key partner to help develop a national approach to data standardization.

Additionally, participants suggested the creation of a national data repository or expanding existing data repositories to improve interoperability and data access, for example the Canadian Partnership for Tomorrow's Health's (CanPath's) data portal. The standardization and curation of data would allow for the merging of datasets and the addition of metadata and other factors (e.g., sequences, markers, environmental and population parameters, clinical data, etc.) to make the data richer and more valuable for identifying patterns and trends. It would also support advanced analytical methods using artificial intelligence and machine learning. This option requires careful consideration of consent agreements and privacy implications that bind existing and future data.

Across the genomics ecosystem, participants spoke on the need to improve data infrastructure, including improving access for researchers and companies to secure high-performance computing, storage capacity, cloud services, and databases. The Digital Research Alliance of Canada (DRAC) and CANARIE were identified as existing organizations that currently advance digital infrastructure in Canada and which could be used to address data infrastructure needs in genomics. To complement this data infrastructure, talent to manage and curate the data, and specialized tools to perform data management and analysis are also necessary.

Adoption and commercialization

To ensure Canada can advance the translation, commercialization and adoption of genomics technologies, participants emphasized the need for the PCGS to improve coordination across the ecosystem. There is currently insufficient coordination between stakeholders resulting in patchy collaboration, limited understanding of different expertise available along the spectrum of technology development, and only a rudimentary understanding of the benefits of genomics by many industry players and the general public.

An ecosystem approach was suggested to address coordination by creating opportunities (e.g., workshops, conferences, public-private partnerships) for interaction between key stakeholders, in order to build partnerships and improve collaboration. This would be especially beneficial to bridge knowledge gaps between researchers/technology developers and end-users/receptors, and ensure user-specific challenges and needs are factored into genomics research and technology development. Coordination could also help raise awareness amongst industry players about success stories and the benefits of adopting genomics technologies and innovations. These types of interactions could help facilitate the rapid translation of genomics research into commercialized innovation and technologies ready for user uptake.

The need for leadership to facilitate and promote coordination across the genomics ecosystem was frequently raised during the consultations. Leadership, particularly through the PCGS, will help identify national priority areas, promote collaborations and connections between industry, academia, and the government, and develop educational and communications strategies to improve public awareness on societal benefits of genomics technologies and innovation.

Participants also discussed how the translation of research into commercial applications lags in Canada due to funding constraints. The small size of the Canadian market, the weak presence of large corporate players (e.g., multinationals in seeds, animal genetics, medical diagnostics, etc.), and the risk-averse nature of venture capital limits commercialization pathways. Participants described the current pathways and funding mechanisms to move from translational genomics research towards commercialization as unclear.

Support for early-stage innovation, scale up of small and medium-sized enterprises (SMEs), market development, and increased access to infrastructure were cited as important considerations for the PCGS. Both the National Research Council of Canada Industrial Research Assistance Program (NRC IRAP) and the United States' Small Business Innovation Research (SBIR)-type grants were identified as effective options to address business development and improve commercialization. In addition, participants called on the government to be the first adopters of genomics technologies, to help de-risk private sector investment and facilitate private sector interest. This would help validate the uptake of genomics technologies and encourage funding for genomics R&D.

Addressing regulatory hurdles was highlighted as important to advancing genomics commercialization and adoption. Participants advocated that regulations should be agile enough to anticipate and accommodate technological advancements, and that regulatory review processes could be streamlined, which would facilitate the movement of new technologies into the Canadian market.

Another component identified as being key to advancing commercialization and adoption is improving access to research infrastructure and applied centers, synthetic biology foundries, and fermentation and processing facilities. Cost-effective access to infrastructure is important for SMEs and researchers with limited resources. This includes access to the NRC's facilities, which respondents flagged were not priced competitively for early-stage SMEs.

Lastly, participants underscored the need to create a robust talent pipeline of HQP with key skillsets in data science, bioinformatics, and business. Fostering an entrepreneurial spirit in science students would help facilitate the adoption and commercialization of complex scientific discoveries, including those involving genomics-based tools and technologies.

Other themes

Other key themes outside of the major pillars highlighted during the consultations include:

Infrastructure

The need for improved infrastructure was a common theme throughout the consultations. Canada does not currently have sufficient and easily-accessible infrastructure to facilitate basic discovery to pilot testing. Existing laboratories, clinics, fermentation facilities, and other research infrastructure lack capacity and capabilities (e.g., equipment, staff, budget, size, diagnostic and testing), while existing digital infrastructure lacks data processing, analytics and storage capacity and has poor interoperability. Access to resources was also noted to be heavily weighted to academic research resulting in long wait times for other users. It was recommended that resources should be made more evenly accessible. Investments to finance new infrastructure could address these issues and help grow the genomics ecosystem and improve commercialization outcomes.

International Collaboration on Data

Given the advances made in international data standards, participants advocated for Canada to align its data standards with international standards-setting bodies or learn from data strategies implemented in other countries such as the UK's Five Safes Framework or Australia's Genomics Information Management System. Aligning standards and practices internationally could help facilitate data sharing between Canadians and researchers/ industry/receptors in other jurisdictions, and would also enable Canadians to participate and collaborate in international genomics-based initiatives such as The Human Cell Atlas and the Global Biodata Consortium.

Outreach and Awareness

The consultations revealed the need to improve private sector and public awareness of genomics and its benefits. Greater awareness and demystifying genomics is necessary to increase youth interest and draw students into genomics-related training streams, and improve receptors'/industry's understanding of how genomics applies to their sector and could help with innovation. To raise awareness, participants suggested public awareness campaigns, outreach, public opinion research, and science communications.

Linkages with other initiatives

The PCGS should establish linkages with other Canadian strategies that identify science, technology and standardized data systems as foundational to Canada's economic success. Some initiatives cited include the Biomanufacturing and Life Sciences Strategy, the National Strategy on Drugs for Rare Diseases, the Pan-Canadian Health Data Strategy, and the National Quantum Strategy.

Genetic Testing and Counselling

Also flagged during the consultations was the need for laboratories, equipment and staff for clinical genomics testing, and regulation of genetic counselling. While these are important considerations, they fall outside the scope of the PCGS.

Sector-specific opportunities

Throughout the consultations, participants spoke on sector-specific opportunities.

Health

Health was identified as the sector with the greatest opportunity and potential for adoption and commercialization in the short-term. Genomics could play a major role in healthcare through disease prevention, assessing health risks, medical testing, therapeutics, personalized medicine and targeted treatments, disease management, and surveillance for infectious pathogens. Genomics research discoveries in health are well-advanced and the sector has already embraced the uptake and use of genomics technologies and innovation. To further advance genomics innovation in health, investments are needed in training, health-related infrastructure, and a federated health data ecosystem. Participants widely encouraged leveraging existing federal investments in the National Strategy for Drugs for Rare Diseases and the Biomanufacturing and Life Sciences Strategy, and building on the recommendations from the Pan-Canadian Health Data Strategy.

Agriculture and Agri-Food

Agriculture and Agri-Food were also identified as sectors of high potential. There are opportunities to further apply genomics, data analytics, cell biology, and other platform technologies to a variety of crops to improve crop resiliency, pathogen surveillance, and disease outbreak monitoring for both crops and livestock. These capacities are increasingly salient in the face of climate change where crops and livestock are especially vulnerable. To further advance genomics innovation in agriculture and agri-food, respondents discussed the need to streamline the regulatory environment. Health Canada's recently announced new transparency initiative (part of its Novel Food Regulations on plant breeding innovation) was viewed as a positive development that could be used as a potential model. It was also noted that there is a need to improve lab infrastructure to support research translation and commercialization in this sector.

Synthetic Biology

Synthetic biology was recognized as a growing field with opportunities to address problems across different fields, including in food, biomaterials, fuels, chemicals, and pharmaceuticals. However, to further advance these opportunities, investments are required in: synthetic biology foundries with advanced data capabilities to accelerate biocatalyst design, development and deployment; training in fermentation and biochemical engineering; and, fermentation development and scale-up.

Environment

Areas related to the environment and the green economy were seen as having great opportunities in the short-term for the adoption of genomics. This includes environmental protection (i.e., biomonitoring, ecological impact assessments, etc.), bioremediation, climate change mitigation, process intensification, biomanufacturing and bioengineered products. To advance this sector further towards commercialization and adoption, investments are needed in eDNA testing, training in related professions such as environmental specialists, fishers and foresters, and intellectual property standards.

In addition to the above mentioned sectors, participants also discussed other sectors with potential for commercialization and uptake of genomics innovation, which included forestry, and fisheries and aquaculture. However, these areas would require sector-specific policies to be advanced.

Final takeaways

Four key themes emerged from the PCGS consultations as the primary takeaways for advancing genomics within Canada's bioeconomy.

Ecosystem approach

Participants highlighted that the PCGS should establish a clear, long-term vision for genomics in Canada that addresses needs across the genomics ecosystem. An ecosystem approach should aim to improve collaboration and coordination between industry, academia, different levels of government, and other key stakeholders. Collaboration and connections across different stakeholders were seen as key to creating linkages necessary for information sharing, raising awareness of existing strengths and opportunities, and connecting talent with the private sector. Funding opportunities should also support the spectrum of technological development from basic research through to commercialization, with timelines long enough to achieve success. An ecosystem approach should also look to improve public and industry education on the value of genomics to improve societal acceptance and commercial adoption.

Federated data framework

A federated data framework was consistently positioned as being necessary to address current data fragmentation. This federated framework should look to incorporate data governance in compliance with international data standards to ensure interoperability of data. National leadership would likely be required to encourage and facilitate collaboration and data sharing between provincial/territorial entities and other relevant stakeholders, while helping promote open data culture and data sharing. A federated data framework should also look to include consent and privacy standards in the collection and management of health data. Lastly, investments in digital infrastructure such as high-performance computing, data repositories, and cloud services were seen as important to ensuring stakeholders have access to the latest technology in order to store and share data, as well as in the talent needed to effectively manage and curate data.

Talent development and retention

To address talent shortages, participants noted that the PCGS needs to improve the talent pipeline in order to help grow the genomics ecosystem. This could include increasing applied training opportunities (e.g., internships, fellowships, co-ops) and building connections between industry and academia/applied learning to facilitate the transition of trainees and graduates into the private sector. It was noted that graduate students, postdocs, and professionals-in-training also require increased funding support to account for increasing expenses. Multidisciplinary training was seen as critical to address key needs in bioinformatics, data science, and business. Promotion of genomics across all levels of education could help inform students of career opportunities, while proactive steps must be taken to ensure EDI in training opportunities.

Strategic initiatives

Targeting strategic initiatives was identified as key to capitalizing on areas of strength and opportunity. By focusing on priority areas, these initiatives could spur interest in, and facilitate the adoption of, genomics technologies.

This type of collaborative initiative could combine the technologies, capabilities, data and resources of multiple companies, research organizations, and other partners, with a focus on leveraging existing strengths. Such a model would accelerate investment to translate genomics research into clinical practice. Precision Medicine was identified by participants as a key example area of opportunity.