From Tools to Products and Processes: The Evolution of Saskatchewan's Agricultural Biotechnology Cluster

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Saskatchewan is one of the three prairie provinces of Canada. Although the population is less than a million, it boasts 47% of Canada's arable land and is home to one of the largest and fastest-growing agricultural biotechnology clusters in the country (Lautermilch, 2002).

The core of the ag-biotech infrastructure is the University of Saskatchewan (U of S), the Agriculture and Agri-food Canada Research Centre (AAFC-SRC), the National Research Council's Plant Biotechnology Institute (NRC-PBI), and the Saskatchewan Research Council (SRC).

The U of S has five life-science colleges on campus:

- Western College of Veterinary Medicine,
- College of Pharmacy and Nutrition,
- College of Medicine,
- College of Agriculture, and
- College of Arts and Science.

The university has additional research capacity with the College of Engineering, as well as major institutions such as the Vaccine and Infectious Diseases Organization (VIDO) and the Canadian Light Source Synchrotron (CLS).

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In 1977, the provincial government leased land from the U of S to establish Innovation Place (Beggs, 2006), a research and development park immediately adjacent to the campus that currently:

- is home to 137 companies and agencies,
- has eighteen buildings and supporting infrastructure with over a million square feet of laboratory and office space,
- has a staff of 2,200, and
- contributes approximately $250 million/yr to the GDP of the province

Early Research Activity

The early focus of research activity in the community included:

- plant breeding, genetics, protection, nutrition,
  - — cereals (wheat, barley, oats)
  - — oilseeds (canola, flax)
  - — pulses (peas, beans, lentils)
  - — forages (grasses and legumes)
- animal health and nutrition,
  - — beef, swine, poultry

With respect to crops research, the major emphasis was on the development of new varieties of commodities for food and feed applications as well as crop-production technologies.

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In the 1980s, our science and political leaders—with great foresight—realized that the emerging science of agricultural biotechnology was potentially a key driver of value for the agriculture sector. Ag-West Bio was established in 1988 by the province of Saskatchewan to provide leadership in the development of this sector. During the period 1992–2002, more than $700 million were invested in the region's infrastructure (McCann, 2002).

Also in the 1980s, there was the realization that genes controlling economically important input traits, such as herbicide tolerance and insect resistance, that were under development—plus other emerging tools, *e.g.* plant-transformation protocols and increasing knowledge of the regulation of gene expression—when commercially introduced, would have a profound impact on the business of food production.

Success Stories

Saskatoon has had many ag-biotech success stories over the years, for example the development of novel vaccines by VIDO (VIDO Report, 2001) and a bloat-reducing alfalfa by Agriculture and Agri-Food Canada (Coulman *et al.*, 2000). However, the greatest economic impact came from the development of canola, now Canada's second most important crop. The canola story has been reviewed in detail by Phillips *et al.* (2001) and by Keith Downey in this volume[1]. With significant research work at NRC-PBI and AAFC-SRC, Saskatoon became the national centre of excellence for *Brassica* development. Considerable work was also done in collaboration with the University of Manitoba.

The NRC and AAFC laboratories had major R&D activity in breeding, molecular biology, chemistry, entomology, pathology and agronomy with strong teaching and research support from the U of S. As a result of this concentration of expertise, a number of multi-national companies moved components of their R&D programs to Saskatoon to be in proximity to the publicly funded infrastructure [scientific expertise, intellectual property (IP), facilities, equipment and money]. Strong public/private collaborations developed and public/private IP was bundled to create commercial products. The first commercial field-planting of a genetically engineered (glufosinate-resistant) canola crop occurred in 1995 (Bijman, 2001) as a result of the collaboration among AgrEvo-PGS, AAFC and NRC-PBI.

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And so, the Saskatchewan ag-biotech cluster was born. The reasons for the early success with respect to the canola example include:

- excellent scientists in public institutions with significant IP assets and a highly transformable, economically important crop (canola),
- provincial government foresight in establishing Innovation Place research and development park immediately adjacent to the U of S, and support for the establishment of Ag-West Bio in 1988,
- the concentration of institutions and scientists on the same campus and immediately adjacent research and development park (Innovation Place),
- the excellent communication, networking and spirit of cooperation among all of the players; and a "can-do" attitude,
- excellent infrastructure (laboratories, equipment and operating dollars),
- strong provincial and federal government support,

[1]Pages 67–76.

- the potential for making money attracted multinational companies to locate some R&D capacity to Saskatoon [AgrEvo (Aventis, Bayer), Monsanto, Dow, DuPont/ Pioneer, *etc.*], and
- successful commercial products in the marketplace with significant revenue potential.

Dynamic Clusters

Biotech clusters are not static; they are dynamic communities, constantly evolving. Our Saskatoon cluster is no different. The major opportunity for the cluster is to capitalize on our comparative advantages by identifying and pursuing opportunities at which we can be globally the best. In that regard, there are potentially huge opportunities in the emerging bio-economy.

So, what is the bio-economy? From the perspective of Ag-West Bio Inc. (AWB), the bio-economy simply involves creating and capturing value from "biological systems."

The oval in Fig. 1 represents the genetic code of a biological system (plant, animal or microbe). Many tools, such those listed on the left side of Fig. 1, have evolved over the years to create value in biological systems for humankind. They include everything from naturally occurring biological systems without any modification through to the use of modern biotechnology to modify the genetic code to create value, such as herbicide

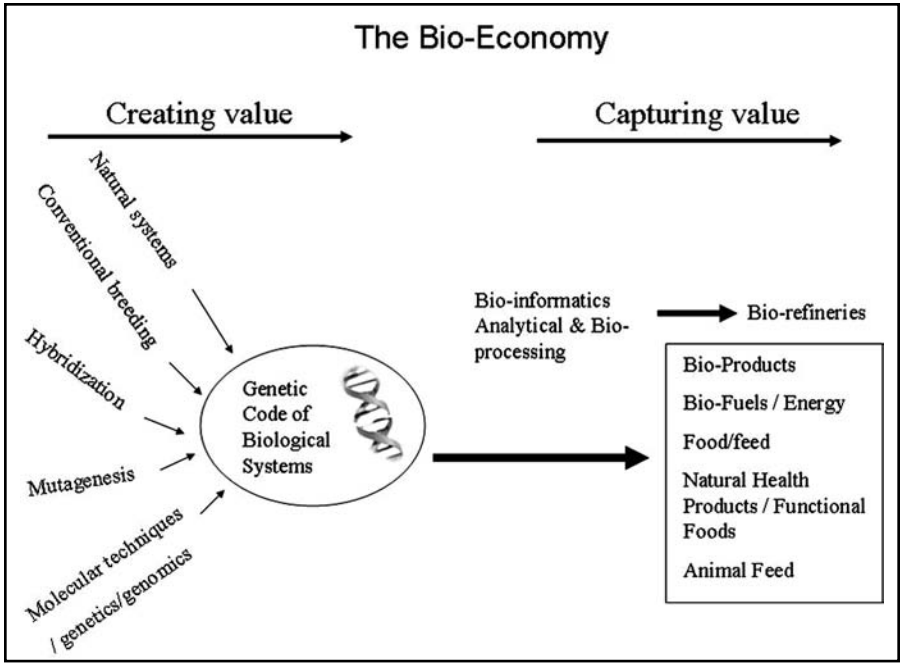

Figure 1. A schematic showing how value is created and captured in the emerging bio-economy.

tolerance in crops. After the research has been completed to create the value, advances in bio-informatics and analytical and bioprocessing technologies can be used to produce a range of products: from natural health products through to biofuels and bio-industrial platforms such as the corn-sugar based platforms [*e.g.* DuPont's 1,3 propanediol (PDO) (DuPont, 2000), ADM's polyhydroxyalkanoate (PHA) (Peterson, 2006), and Cargill's polylactic acid-PLA (Brady *et al.* 2005)].

Strategies and Strengths

The challenge and the opportunity for each region are the ability to understand and to effectively exploit global comparative advantage. Our strategy at Ag-West Bio for Saskatchewan is twofold:

- marketing our excellent bio-economic infrastructure, and
- identifying and targeting strategic opportunity sectors.

In terms of marketing the infrastructure globally, we promote ourselves as a solution-provider:

> Looking for reliable, quality ingredients, analytical or processing capabilities, innovative research, or a path to commercialization? From research to market, Saskatchewan offers the Solution!

We have an extensive list of assets throughout the full spectrum of the research-to-market value chain. These include a robust R&D capacity; analytical, bioprocessing and bio-informatics capacity; and support services and private industry. Examples of these assets include:

- **Research and development capacity**
  - *Environmental technologies*
    - Biological controls (weeds, insects and diseases)—U of S Department of Plant Sciences, AAFC-SRC, NRC-PBI, Saskatchewan Wheat Pool (SWP)
    - Biotic / Abiotic Stress Resistance—U of S Department of Plant Sciences, AAFC-SRC, NRC-PBI, SWP
    - Seed oil modification—U of S Departments of Plant Sciences and Chemical Engineering, AAFC-SRC, NRC-PBI
    - Plant Pathology—U of S Department of Plant Sciences, AAFC-SRC, NRC-PBI
  - *Bioenergy, bioproducts, renewable industrial feedstocks/biorefineries*
    - Bio-energy/fuels—U of S College of Agriculture and Chemical Engineering, Petroleum Technology Research Centre (PTRC)
    - Bioproducts—U of S Departments of Plant Sciences and Chemical Engineering, AAFC-SRC, NRC-PBI, SRC
    - Renewable feedstock platform—U of S, AAFC-SRC, NRC, SRC

- — *Health and nutrition technologies*
  - Human health and nutrition—U of S Department of Microbiology & Food Science, Colleges of Nutrition & Pharmacy and Medicine
  - Animal health and nutrition—U of S Department of Animal & Poultry Science, College of Pharmacy & Nutrition, Western College of Veterinary Medicine (WCVM), VIDO, SRC

- **Analytical and bio-processing capacity**
  - — Canadian Light Source Inc.
  - — Innovation Place Bio-Processing Centre
  - — Saskatchewan Research Council
  - — Phenomenome Discoveries
  - — Saskatchewan Food Industry Development Centre
- **Support services**
  - — Greenhouse/field trials—AgQuest, ICMS, AAFC, Prairie Plant Systems, Innovation Place
  - — Diagnostics—Phenomenome Discoveries, Bio-ID, Prairie Diagnostics, CFIA, Genserve, Bovacan
  - — Funding—AWB, Foragen, Golden Opportunities, Agriculture Development Fund (ADF), NRC's industrial research assistance program (IRAP), Crown Investment Corporation (CIC), others
  - — Economic development—AWB, Saskatoon Regional and Economic Development Authority (SREDA), Innovation Place, U of S Industry Liaison Office
- **Private-sector companies**
  - — *Environmental technologies*
    - Inoculants—Philom Bios, Becker Underwood
    - Ag-Biotech—Bayer, Monsanto, BASF, Pioneer, Performance Plants, Syngene, Agrisoma, aDNAdvance
    - Biocontrol—Heads-up Plant Protectants, Peacock Industries
    - Organic waste digestor—Clear-Green Environmental
  - — *Bioenergy, bioproducts, renewable industrial feedstocks/biorefineries*
    - Biomass energy—Zelensky's Saw Mill; Nipawin NewGen Co-op
    - Grain ethanol—Poundmaker, Noramera Energy, Husky, others planned
    - Fiber and composites—Biolin, Bio-Fibre Industries, Bio-Hemp Technologies, Hemptown
    - Biodiesel—Milligan BioTech, Saskatoon DSG

— *Health and nutrition technologies*
  - Feed—MCN Bioproducts, GNC BioFerm, Guardian Phenomenome, Bio-ID
  - Health and nutraceuticals—Bioriginal, Fytokem, Emerald Seeds, Infra-Ready, BioNatCom, Bio-Diagnostics, Phenomenome, Bio-ID

In considering our general areas of strength, we look at some of the current global economic drivers and consider how transitioning to a renewable bio-economy either solves problems or adds value in some way. Major global economic drivers that will be impacted by the transition to a bio-economy—where Saskatchewan can be a leader—are:

- energy
- health
- environment

In terms of bio-energy opportunities, Saskatchewan will be a major player in ethanol and biodiesel production. We also have the capacity to be a player in biogas and a biomass-based hydrogen economy.

With respect to the environment, our renewable fuels will contribute to reduced greenhouse-gas production. We will develop alternatives to petroleum-based feedstocks for the production of a range of industrial and consumer products. These will be carbohydrate- and oil-based platforms. And we will continue to introduce biological alternatives to pesticides and chemical fertilizers.

We will also be a major player in bringing Canada's healthcare system back from the brink. Currently, it is primarily a reactive system: one gets sick, goes to the doctor, gets some kind of intervention and gets well. When one looks at the skyrocketing cost of this system to our public treasuries and the age demographics of our population, clearly it is not sustainable. We believe that the future healthcare system will involve a shift to a more-balanced wellness model that will include better nutrition, better understanding of the relationship between the food that we eat and the benefit or disease that it may cause (nutrigenomics), diagnostic tools to understand disease predisposition, and the greater use of natural health products, nutraceuticals and functional foods. The Saskatchewan bio-economic cluster is well poised to exploit the agriculture- and nutrition-anchored wellness opportunity for the benefit of Canada.

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In Conclusion

Saskatchewan is evolving from a tool-based ag-biotech cluster to an outcome-based bio-economic cluster based on:

- global marketing of the infrastructure (Solutions), and
- becoming a global leader in specific strategic technology outcomes:
  - — energy
  - — health
  - — environment

This is an extremely exciting time when agriculture and other renewable-resource-based sectors are undergoing transformational change. For agriculture, advances in science are creating opportunities for Saskatchewan to:

- develop innovative, environmentally sustainable production systems,
- reposition agriculture as part a wellness solution to the healthcare crisis in Canada,
- move towards energy security through the exploitation of biobased feedstocks,
- expand agriculture beyond traditional food and feed to include biobased renewable feedstock platforms for the production of industrial and consumer products, bio-composites, natural health products, biochemicals and biopharmaceuticals, and
- facilitate the development of a number of biorefineries to maximize economic impact.

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As president and CEO of Ag-West Bio, **ASHLEY O'SULLIVAN** is responsible for working with the board of directors to establish the strategic direction and focus for Ag-West Bio in support of the growth of the bio-economic sector in Saskatchewan.

Born in Cork City, Ireland, he completed a BSc and PhD at the University College Cork before moving to Canada in 1973 for a research associate position at the University of Alberta in the Plant Sciences Department. At Monsanto Canada he was responsible for R&D in Western Canada. In 1978, Dr. O'Sullivan joined the team at Agriculture Canada and served as research head at the Lacombe Research Station; assistant director at the Lethbridge Research Station; Director of the Swift Current Research Station; and director of the Saskatoon Research Centre.

While with Agriculture and Agri-Food Canada, he obtained a wealth of international experience as the Canadian principal advisor for the India Dryland Project in Hyderabad; managing a CIDA-sponsored research project at Rio Grande do Sul, Brazil; and as research advisor to the Hebei Dryland Project in China.

O'Sullivan also spent a year as the managing director of CABI Bioscience in the United Kingdom and has served on a number of management boards and advisory committees.