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See table of contents

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STEVEN TURNER and HEATHER MOLYNEAUX

Agricultural Science, Potato Breeding and the Fredericton Experimental Station, 1912-66

HISTORIES OF CANADA'S FORMIDABLE ACHIEVEMENT in agricultural science and crop breeding have usually been cast in the heroic vein, their subject interpreted as a series of episodes in the progressive and benign advance of a rational understanding and control of nature. This scientific story has dovetailed neatly with accounts of Canada's agricultural history that stress the modernization of farming or that emphasize the concomitant themes of efficiency and productivity growth. Because the development of prairie grains, rust-resistant wheats and canola take pride of place in most accounts of agricultural science in Canada, those histories have focused on events played out mainly in central Canada and the west. Nevertheless, region and regional influences seldom play a central role in these accounts – a tacit tribute to faith in the universality (or at least the internationalism) of natural science, its methods and the advancing front of rational technological control spun off by that science.

This paper explores a less-examined front in the history of Canadian agricultural science. It reviews the important scientific research on the potato and potato agriculture conducted at the federal Dominion Experimental Station (now the Canadian Potato Research Centre) in Fredericton, New Brunswick, from the station's founding in 1912 through to the mid-1960s. Already by the end of this period, the station ranked among the top five or six potato research institutes in the world, and it could point to important achievements in potato virus research, entomological work, theoretical and quantitative genetics, and basic agronomic techniques. Our focus, however, is on the station's efforts, initiated formally in 1934, to breed new varieties of potatoes. That development agenda originally focussed on the quest for disease resistance, but these objectives were expanded significantly in the 1950s and early 1960s to include commercial, agronomic and industrial considerations largely absent from earlier work. By 1982, 11 of the 59 cultivars registered in Canada had been developed in Fredericton, and a recently released variety, the Shepody, was soon to go on to vast commercial success.

Rather than offer an heroic interpretation of these signal achievements, however, this paper suggests that the broadening of the station's breeding programme in the 1950s represented a partial retreat from the original objectives of the disease-resistance breeding programme introduced in 1934, a concession to the fact that those objectives could not be achieved as originally envisioned. It examines how research agendas were related to the structural transformation of potato agriculture in New Brunswick during the key decades of the 1950s and 1960s and it argues that the

Steven Turner and Heather Molyneaux, "Agricultural Science, Potato Breeding and the Fredericton Experimental Station, 1912-66", *Acadiensis,* XXXIII, 2 (Spring 2004), pp. 44-67.

limitations of resistance breeding accelerated the shift of focus toward pesticides and government-enforced phytosanitary systems.

This story demonstrates how science contributed to the structural transformation of the potato industry in the region and also, conversely, how social, political and economic forces helped to reshape research agendas and scientific expectations. This story can be understood at two levels. First, the style of potato science in Fredericton evolved over time and mirrored changing cultural ideals about science and agriculture. Potato science was shaped by institutional responsibilities and organizational forms, and by competing ideals, bureaucratic alignments and forms of professional consciousness among scientists. Second, and on a broader scale, the station's breeding programme responded to the changing political economy of New Brunswick's agricultural sector, especially in the 1950s and 1960s.

These considerations pose significant questions about the supposed universality of scientific and technological change and its relationship to region and regionality. By the 1950s the potato-breeding programme at the Dominion Experimental Station in Fredericton had achieved national, not just local or regional status. Its scientists interacted regularly with researchers around the world, and provincial developments in potato agriculture and in agricultural science reflected similar changes occurring all over Europe and North America. But for all that, the particular dynamic of scientific change at work at the Fredericton station is explicable only within the context of New Brunswick and the region of which it is a part.

The Experimental Farm System

From its creation by Parliament in 1886 until more than two decades later in 1907, the Experimental Farms Branch of the Canadian federal Department of Agriculture consisted of the Central Experimental Farm outside Ottawa, the branch's five divisions (all headquartered on the central farm) and its four branch farms in Nova Scotia, Manitoba, the North-West Territories and British Columbia. Beginning in 1907, however, the number of experimental stations (only the original five were officially designated farms) began to multiply rapidly, partly due to the efforts of the redoubtable William Saunders, first director of the branch.[1] Not all the new installations, however, were stations. The Division of Entomology and the Division of Botany and Plant Pathology of the Experimental Farms Branch also opened laboratories across the country, not all of which were connected with, or located on, a farm or station. By 1913, two years following Saunders' retirement in 1911, the Experimental Farms Branch had grown to ten divisions (all in Ottawa), eighteen farms

1 The official history is T.H. Anstey, *One Hundred Harvests. Research Branch Agriculture Canada 1886-1986*, Research Branch, Agriculture Canada, Historical Series no. 27 (Ottawa, 1986). Available online at http://collection.ic.gc.ca/agrican/pubweb/titles_e.asp. In addition to the sources listed in the notes, we are grateful to a number of former station scientists and agricultural officials who agreed to be interviewed. We thank the various members of the administration of the Potato Research Centre, and especially PRC Librarian Richard Anderson, for their cooperation with this project. We are grateful to the archivists at the New Brunswick Provincial Archives (PANB) and the National Archives of Canada (NA) for advice and assistance. This study was funded by Social Sciences and Humanities Research Council of Canada.

or stations (including the central farm) and nine entomology or plant pathology laboratories.[2]

During these decades the organization of federal agricultural research underwent significant changes. In 1914 the Entomological Division of the Experimental Farms Branch was reconstituted as an autonomous branch, and its new director, Dominion Entomologist C.G. Hewitt, embarked on an ambitious programme to expand the entomological laboratory facilities in Ottawa and across the country. In 1937 a more significant reorganization saw the Department of Agriculture reconstituted into four functional "Services": Production Services, Marketing Services, Experimental Farms Services and the Science Service. The new Science Service combined the former Entomological Branch with three divisions of the old Experimental Farms Branch. Its creation marked a victory for elements within the department urging a division that would be explicitly "scientific" and "research-oriented" and served to hold at bay the ambitions of the National Research Council, which, as Stéphane Castonguay has argued, was eager to carve out its own slice of the agricultural research pie.[3]

For all its initial success, William Saunders' creation wrestled from its inception with persistent organizational and conceptual tensions. One was the struggle of the regional farms and stations for operating autonomy versus the instinct of Saunders and his successors to centralize operating control and most advanced research on the central farm and its divisions in Ottawa. Another was the balance to be struck between research per se and what would later be called extension services – the responsibility of the stations to assist and instruct the farmers whom the experimental farm system regarded as its natural clients. Perhaps most important was the proper trade-off between a practical, utilitarian and theory-free approach to agricultural science and more academic, theoretical and discipline-based visions. The divisional structure that William Saunders imposed upon his experimental farm system in 1886 – field crops and husbandry, cereals, chemistry, entomology and botany and horticulture – reflected the tense compromise between an agricultural science modelled upon the scientific disciplines and one modelled upon the practical and economic concerns of the farm enterprise itself. That tension was to surface again in 1937, when the newly created Science Service moved to restructure agricultural research in Canada much more directly along the compartmentalized lines of the scientific disciplines.

Agronomic Science in Fredericton: The Early Decades

Since at least the 1850s, improving farmers and enlightened elites in New Brunswick, modestly assisted financially by their provincial governments, had tried to promote the practical improvement of agriculture through grants to local agricultural societies, sponsorship of provincial exhibitions and the founding of province-wide umbrella organizations. The New Brunswick provincial government set up its Department of Agriculture in 1888, but it grew slowly, with 7 employees in 1910 and

2 Anstey, *One Hundred Harvests*, pp. 33-8.

3 Anstey, *One Hundred Harvests*, pp. 49-65; Robert Glen, "Organization of the Research Branch of the Canada Department of Agriculture, an Historical Review", *Agricultural Institute Review*, 17 (1962), pp. 18-20, 45-6; Stéphane Castonguay, "Fédéralisme et centralisation de la recherche agricole au Canada: dynamique scientifique et compétition institutionelle", *Bulletin d'histoire poltique* 7, 3 (1999), pp. 21-39.

21 by 1918. The new department encouraged progressive agriculture, assisted immigration from abroad onto New Brunswick farms, superintended butter and cheese manufactures and promoted agricultural schools.[4]

Although these activities were often described as promoting "scientific" agriculture, research per se emerged exclusively as a federal, not a provincial, area of competence, and provision for actual investigations in New Brunswick had to await the expansion of the experimental farm system. A small General Entomological Laboratory was established in Fredericton on the University of New Brunswick campus in 1911 by the Entomological Division of the Experimental Farms Branch (soon to become an autonomous branch). In 1915 the Division of Botany and Plant Pathology organized a laboratory on the second floor of the old Fredericton post office. The big prize, however, was an experimental station. After sufficient local pressure had been applied to Ottawa, a site was chosen on the south side of the St. John River, three miles below the centre of the city and still within the municipal boundaries. Four hundred and fifty acres were purchased in September 1912, and subsequent expansions brought the station to 764 acres by 1960.[5] The Fredericton station eventually came to house the two laboratories even though, before 1959, they were administratively independent and did not report to the station superintendents.[6]

The types of agronomic investigations performed at the Fredericton station during its early decades, as well as the rhetoric employed by station superintendents in the annual reports, bring readily to mind the "Baconian" style of science described as characteristic of the Victorian period in North America.[7] Experimental work on potato

4 Lorna Williams, "From Agricultural Improvement to Industrial Affirmation: The Evolution of the New Brunswick Provincial Exhibitions, 1852-1883", M.A. thesis, University of New Brunswick, 2003; J.D. White, "Speed the Plow: Agricultural Societies in Pre-Confederation New Brunswick", M.A. thesis, University of New Brunswick, 1977; E.B. DeMerchant, *From Humble Beginnings. The Story of Agriculture in New Brunswick* (Fredericton, 1983), pp. 39-63. For a Nova Scotia comparison, see Richard A. Jarrell, "Science and Public Policy in Nineteenth-Century Canada: Nova Scotia Promotes Agriculture", in Paul A. Bogaard, ed., *Profiles of Science and Society in the Maritimes prior to 1914* (Fredericton, 1990), pp. 221-42.

5 The most comprehensive history of the Fredericton station is a 66-page undated ms at the library of the Fredericton Potato Research Centre: R.G. White, "History of the Fredericton Experimental Station/Research Station, 1912-1970" (n.d.). Other historical sketches include *Canada Agriculture Research Station Fredericton N.B.* (Ottawa, 1961), 12 pp. and Rodrigue Hurtubise, "History of the Fredericton Research Station 1912-1986" (12 p. 1985 ms at Potato Research Centre library, Fredericton). D.A. Young et al., *Fredericton Research Station 1912-1987,* Research Branch, Agriculture Canada, Historical Series no. 35 (1987) is a useful account of research pursued at the station in various fields and available online at http://collections.ic.gc.ca/agrican/pubweb/titles_e.asp. On the experimental farm at Charlottetown, Prince Edward Island (founded in 1909), see Mary B. Bourdon, *Charlottetown Research Station 1909-1984,* Research Branch, Agriculture Canada, Historical Series no. 19 (1984).

6 In 1925 the Plant Pathology Laboratory was moved to the grounds of the Fredericton station, and in 1938 a new laboratory building with attached greenhouse was erected for its use. The original agricultural entomology laboratory spun off several units. Entomological control studies were done at the general Entomological Laboratory (which successively occupied various sites on the UNB campus), but virus vector research, which began around 1940, was housed in the Laboratory of Plant Pathology (since 1925 on the grounds of the Fredericton station) and from 1950 in facilities of its own.

agronomy, for example, was presented as a diverse series of mostly theory-free optimization experiments carried out on many factors related to potato cultivation. Fredericton agronomists investigated optimum row spacing, plant separation, manure and fertilizer applications, and cultivation frequency. They systematically compared immature versus mature potatoes as seed, large versus small seed pieces, long versus round and sprouted versus unsprouted tubers for producing early crops; they also compared the benefits of spraying versus dusting for fungus. The style of early station research also mirrored the older tradition of what Suzanne Zeller has called "inventory" science, as variety screening for yield was the major focus of experimental work.[8] In the first decade, station agronomists inventoried hundreds of different potato varieties, an important service given the relatively unregulated use of variety names at the time. Theory- or laboratory-based investigation was little in evidence among Fredericton station agronomists, although it played a larger role in the work of plant pathologists and entomologists in the sister services.

During this period, agronomists published their experimental results almost exclusively in Agriculture Canada reports and bulletins aimed at provincial farmers and at other farms and stations; agronomists performed their investigations and presented the results in a manner readily accessible to improving farmers. Experimental methods were straightforward and statistical analyses elementary. Confidence-interval and significance statistics did not make their appearance until the late 1930s, with the first regression analyses coming much later. This was a "democratic" style of science that minimized the distance between scientist and farmer and served the double function of better assisting farmers and averting the ever-present danger that the station's work might be seen by its clients as impractical, highfaluting or tending to the ivory tower. The *Maritime Farmer and Co-operative Dairyman*, the region's major agricultural newspaper, echoed this democratic ideal approvingly in its consistent support for the station and its work. All farmers do experiments constantly on new varieties and practices, the paper claimed on several occasions, but because such experimentation is time-consuming and expensive, that work could be more efficiently carried out on the farmers' behalf by the Dominion Experimental Station in Fredericton.[9] Thus efficiency and convenience, not any particular form of scientific or agricultural expertise possessed by station agronomists, was what justified the station's existence. This popular interpretation, encouraged by the station's own style and rhetoric, echoed a very old faith in science as universal commonsense and rationality, codified and reduced to method.

The early mandate of the Experimental Farms Branch imposed responsibility for

7 Suzanne Zeller, *Land of Promise, Promised Land: The Culture of Victorian Science in Canada*, Canadian Historical Association Historical Booklet no. 56 (Ottawa, 1996), pp. 1-21; Suzanne Zeller, *Inventing Canada: Early Victorian Science and the Idea of a Transcontinental Nation* (Toronto, 1987), esp. pp. 4-5; Carl Berger, *Science, God, and Nature in Victorian Canada*: *The 1982 Joanne Goodman Lectures* (Toronto, 1983), esp. pp. 3-27, 31-50; Trevor H. Levere and Richard A. Jarrell, eds., *A Curious Field-book: Science and Society in Canadian History* (Toronto, 1974), esp. p. 1-24; Bogaard, *Profiles of Science and Society in the Maritimes*; Alan I. Marcus, *Agricultural Science and the Quest for Legitimacy: Farmers, Agricultural Colleges, and Experimental Stations, 1870-1890* (Ames, Iowa, 1985).

8 Zeller, *Inventing Canada*, pp. 4-5.

9 *Maritime Farmer and Cooperative Dairyman*, 11 September 1917, p. 566; 20 July 1946, p. 6.

extension as well as research functions, and this responsibility had implications for the science that was conducted in Fredericton. Just as most New Brunswick farms pursued mixed farming with limited specialization, the station personnel studied and maintained on display all elements of the particular mix of agricultural activities being pursued in the province. As part of its investigative activities, the station periodically reported the input-factor costs in producing an acre of potatoes on the station, and compared them with the yield, market price and the resulting per-acre profit from the crop. The exercise served the extension function by providing farmers with a practical yardstick by which they could assess their own management performance.

The Dominion Experimental Station in Fredericton also served its extension mandate by providing models for farmers' assessment and emulation. Earlier calls to set up a model farm to inspire and instruct New Brunswick farmers had come to nothing, but in 1916 the new federal installation initiated a series of illustration stations around the province, and the staff regularly provided direct instruction and advice to farmers at field days, agricultural association meetings and by correspondence. The Fredericton station also made itself the focus of agricultural life in New Brunswick. The station's first Open House, held in 1916, drew 1,200 farmers and their families from around the province; the second drew 3,000 and, before wartime cutbacks in the 1940s, the "At-Homes" had expanded to three-day events. These affairs combined the promulgation of information about progressive farming with rhetorical celebrations of rural life and farming ideology, and featured guided tours of the Fredericton station's facilities, opportunities for consultation with station personnel, speeches by local and visiting scientists and politicians and dinners served up by the Fredericton Women's Institute.[10] In conformity to an agenda set by William Saunders himself, the Fredericton station, like the Central Farm, invested heavily in flowers, hedges and ornamentals, not only so that its grounds would attract visitors and picnickers, but also (as the *Maritime Farmer* noted in 1934) so that visitors would be inspired to emulate the farm practices they observed.[11]

Outreach to the farm community in these respects came easy to the Fredericton station because during its early years it *was* in some respects like a New Brunswick farm. The superintendent lived on the station, where he entertained visiting dignitaries (a new house was built for the superintendent in 1926). Some other employees, from labourers to scientists, rented houses on the station grounds, and employees could be supplied (at a charge) with vegetables, eggs and sometimes meat. Crops and animals produced on the farm were sold, providing a return to the Receiver General equivalent (in the early 1940s) to almost a fifth of the station's budgetary appropriation.

Local and regional identification also seems to have been strong among station personnel, even though Ottawa insisted on minute control over their activities and expenditures. The station's first director, New Brunswicker W.W. Hubbard, resigned in 1921 over what he regarded as heavy-handed Ottawa bureaucrats who were indifferent to Maritime interests, although he judged that at the Fredericton station

10 *Maritime Farmer and Cooperative Dairyman*, 11 September 1917, p. 566; 5 September 1922, p. 371.

11 Julie Harris and Jennifer Mueller, "Making Science Beautiful: The Central Experimental Farm, 1886-1939", *Ontario History,* 84, 2 (June, 1997), pp. 103-23; *Maritime Farmer and Cooperative Dairyman*, 5 June 1934, p. 8.

"the officials seem to be N.B. minded".[12] The energetic Gilbert C. Cunningham began his career in the federal service as head of the Plant Pathology Laboratory in Fredericton. But he rapidly became the indefatigable champion of the New Brunswick potato industry and moved on to the provincial civil service as the first director of the provincial government's Potato Production and Marketing Service. In all respects, the image of scientific expertise that the Fredericton station presented dovetailed with its conception of its public responsibility and extension function and continued to reflect ideals of agricultural science laid down in the Victorian era.

The Potato-Breeding Programme

In 1934 the research agenda of the Fredericton station was broadened in a way that moved the style of agricultural science practised there in new directions. Although the station had screened potato varieties and investigated cultivation and management practices very intensely since 1912, potato breeding and variety development had never been performed systematically in Fredericton or elsewhere in Canada. In 1934, however, the Dominion Department of Agriculture initiated a major program of variety development in Fredericton. Louis C. Young, station horticulturalist, and D.J. MacLeod, Officer-in-Charge of the Dominion Pathological Laboratory, were sent to tour American facilities. Their report lauded the benefits of scientific specialization and argued that "the weight of evidence obtained . . . [favours] searching for disease resistance rather than other attributes in all primary selections". This recommendation that disease resistance rather than improved agronomic characteristics should be the primary focus of the breeding program continued to guide variety-development work at Fredericton for the next two decades.[13] Between 1933 and 1946, Fredericton agronomists produced some 150,000 seedlings from hybrid crosses and screened them for disease resistance and acceptable commercial properties. Approximately half the seedlings studied were bred for resistance to late blight disease and its causal fungus *Phytophthora infestans*, using the wild Mexican potato species *Solanum demissum* as a source of resistant germ plasm. The resistance programme expanded to include mosaic disease (1934), common scab (1936) and leaf roll disease (1937).[14]

Ottawa's consent to a major programme of variety development was probably motivated in part by the fact that the United States had initiated its own National Potato Breeding Program in 1929. Its decision to locate the programme in Fredericton owed much to the initiative of local scientists, but it was also influenced by the fact that New Brunswick potato production, while still small in comparison to that of

12 H.H. Hubbard, "Life and Times in New Brunswick, 1866-1945", MC16/MS1, PANB, p. 3.

13 D.J. MacLeod and L.C. Young, "Report of Trip to Institutions in the United States in Connection with Co-operative Potato Breeding Project", (57-page 1934 ms at Potato Research Centre library, Fredericton).

14 Experimental Station Fredericton, N.B., *Report of the Superintendent* . . . [later title variations: *Results of Experiments*, *Progress Report*, *Research Report*] (Ottawa), annually 1921-1930, 1937 [covering 1931-36], 1948 [covering 1937-47], 1953 [covering 1948-52], 1958 [covering 1953- 57], 1962 [covering 1958-60], 1963 [covering 1961-62], 1965 [covering 1963-64] and 1967 [covering 1965-66]. We are indebted to Eric Davies for access to unpublished materials held by him under the title "Seminars, Press Articles, and Talks Given by H.T. Davies 1950-1978" and referenced here as "Davies Papers".

Ontario and Quebec, was the largest in the three Maritime Provinces and increasing.[15] More interesting is the federal Department of Agriculture's decision to focus the breeding programme on the development of disease-resistant varieties, with less concern for improving agronomic properties such as size, yield, taste, dry-matter content, hardiness or storage capacity. In this decision the department was surely led by the expectation that potato research would emulate the major advances then being made in creating rust-resistant varieties of prairie grains. But the explanation also lies in the nature of the potato itself.

Cultivated potatoes are more susceptible to fungal, viral and bacterial pathogens than any other major crop. One reason for this is their narrow genetic base: almost all cultivated potatoes are varieties of a single subspecies, *Solanum tuberosum,* that was introduced into Europe from South America in the early modern period and subsequently isolated from the sources of new germ plasm present in the many wild species and primitive cultivated varieties that exist in South and Central America. Potatoes' vulnerability to disease also follows from the fact that they are propagated almost exclusively by vegetative means, from "seed tubers" or seed tuber-pieces held over from the previous year's crop, not from "true" or "botanical" seed formed in a berry after pollination. While relatively few diseases can be transmitted from one plant generation to the next through botanical seed, many are readily transmitted through seed tubers, with viral diseases being particularly insidious in this regard.[16]

Concern about potato disease was on the increase among growers in Eastern Canada after 1915, partly because potato diseases seemed to be becoming actually more prevalent and partly because of improved scientific and bureaucratic potential for detecting and publicizing them. In normal years the fungal disease late blight, the most feared of all potato diseases, could be controlled by the ubiquitous Bordeaux mixture fungicide, but thousands of smaller farmers in New Brunswick lacked the spraying and dusting equipment required or could not afford the chemical. In extreme blight years (1927, 1928, 1932, 1936) the fungicide provided little protection anyway; in 1926 potatoes at the Fredericton station were so badly blighted that the entire crop had to be destroyed, curtailing or eliminating potato investigations at the station for several years. The virus-induced "mild mosaic" disease, of great concern in the 1920s, did decline in importance after 1930, but it was replaced by what appears to have been an increasing incidence of other diseases, including common scab, bacterial ring rot and the viral disease leaf roll. So rampant were viral diseases among the potato stocks at the Fredericton station in 1943 that breeders were obliged to transfer the field-based elements of their programme to an isolation station, a practice increasingly common among potato-breeding programmes around the world. The New Brunswick site chosen was in Albert County, relatively free from aphid-vectors and located at a distance from other potato farms. What toll disease took among private producers is harder to determine, but market data that show 1920 to 1935 as a period of wildly

15 *Potato Historical Series*. Statistics Canada, Agricultural Division, Crops Section (Ottawa, November 1992). In 1934, total Canadian production was 2,181,600 tonnes, with PEI producing 218,800, Nova Scotia 111,300 and New Brunswick 314,700 tonnes. New Brunswick production did not regularly surpass that of Ontario or Quebec until the late 1950s.

16 Hans Ross, *Potato Breeding – Problems and Prospects* (Berlin and Hamburg, 1986); J.G. Hawkes, *The Potato. Evolution, Biodiversity and Genetic Resources* (London, 1990).

fluctuating prices, production levels and yields per acre suggest significant disease problems.[17]

The new disease consciousness that motivated the breeding programme in Fredericton also owed its origins to the growing economic importance of potato exports, especially of seed potatoes, from New Brunswick and Prince Edward Island.[18] That gave disease-consciousness a political face. In 1909 the fungal disease "wart", unknown in North America but already serious in some parts of Britain and Europe, had been detected in Newfoundland. The discovery prompted a flurry of federal legislation to prevent its spread into Canada. In 1913 powdery scab was discovered in New Brunswick potatoes bound for Maine, and the Americans responded with an embargo on all Canadian potatoes. In 1914 Bermuda placed an embargo on Nova Scotia potatoes, complaining that they were "degenerate" and low yielding. The embargos were particularly damaging, since they affected Eastern Canada's seed-potato export trade, a still-small but lucrative corner of the industry dominated by well-do-to and politically influential grower-shippers. As a step to restore confidence in Canadian potato exports, the federal government created a Seed Potato Certification Service by which, at the request of farmers, federal inspectors would conduct field inspections to determine if the growers' fields were disease-free within accepted parameters. The system was officially begun in New Brunswick in 1918 and, by 1924, was in effect in all Canadian provinces. The chief architects of the certification system were Hans Güssow (1879-1961), Dominion Botanist, and two of his very talented lieutenants, Paul A. Murphy and Gilbert C. Cunningham, respective heads of the plant pathology laboratories in Charlottetown and Fredericton.[19]

The program of large-scale variety development triggered by this new disease-consciousness represented a kind of agricultural science at odds with visions of a democratic science that minimized distinctions of expertise as well as with the theory-wary vestiges of Baconianism. Potato breeding is a labour-intensive activity involving extensive record keeping. In addition to technical training, it necessitates horticultural intuition, gardeners' craft skills, considerable manipulatory ability and the theoretical insights of Mendelian genetics. But potato breeding differs from comparable work on other species because of the widespread infertility problems among *tuberosum* varieties and their hybrids and, in the early Fredericton program, by differences in ploidy (chromosomal number) between *S. tuberosum* and *S. demissum*. To counteract these fertility problems, immature stamens must be removed from the seed parent to

17 *Potato Historical Series* (1992).

18 It is unclear how early seed export began. The New Brunswick Seed Potato Growers Association was organized in 1924 and growers shipped some 16 freight cars of seed potatoes to the Atlantic states in that year. In the 1930s New Brunswick opened up lucrative export markets with Cuba and South America. See the New Brunswick Department of Agriculture *Annual Report*, 1924, p. 64 and 1908, p. 20. See also the *Report of the Royal Commission on the New Brunswick Potato Industry* (Fredericton, 1962), pp. 47-50.

19 Ralph H. Estey, *Essays on the Early History of Plant Pathology and Mycology in Canada* (Montreal & Kingston, 1994), esp. pp. 42-73, 167-74, 215-20, 306-13; G.C. Ainsworth, *Introduction to the History of Plant Pathology* (Cambridge, 1981), esp. pp.186-94; Canadian Food Inspection Agency, *Seed Potato Certification Manual* (31 May 2002), ch. 1: "Background and Policy"; M. Chisnall Hampson, "History, Biology, and Control of Potato Wart Disease in Canada", *Canadian Journal of Plant Pathology*, 15, 4 (December 1993), pp. 223-44.

prevent the plant from self-pollinating, the plant artificially pollinated with pollen from the chosen pollen parent, and true seeds collected from the mature seed pod. The resulting seedlings from the hybrid seed must be grown out, selected over several years for horticultural characteristics, and finally, when manageable numbers have been obtained, exposed to a pathogen and evaluated for disease resistance. The most promising plants are retained for further hybridization, usually backcrossing with an *S. tuberosum* line to restore commercial characteristics of tuber size and number while maintaining the resistance characteristic. So much of *S. tuberosum*'s cultivated character is usually lost on the first wild cross that seven or eight generations of careful backcrossing and screening are required to restore commercial potential. Moreover, the time required to develop a new variety from first out-cross to commercial release can be 8 to 15 years. Development work on this scale of organization and investment, depending as it did upon access to rare Mexican and South American plants, clearly surpassed the capacity of individual farmers; not even at the level of rhetoric could it be plausibly assimilated to the ideal of a "democratic" science, and there were no further attempts to do so.

Still, the break with older ideals and practices was not definitive in the early years of the breeding program. *S. tuberosum* is a tetraploid species, meaning that a normal cell possesses four rather than the usual two sets of chromosomes that constitute the genome of many other important crop species like maize, barley, rye and rice. Tetraploidy makes it very difficult to apply Mendelian theory and techniques in order to deduce the genetic make up of parental varieties or to predict the characteristics of offspring from sexual crosses of parental varieties, and it increases the range of variability that offspring are likely to show for particular traits.[20] As a consequence, through the 1930s and 1940s potato breeding retained much of the atheoretical, trial and error screening focus that had characterized potato science at the Fredericton station earlier. It was still removed from the "hard" biology and genetics that would characterize the breeding programme later.

But the early breeding program retained the persistent optimism that nature's genetic bounty would ultimately make possible decisive victory over disease. Scientists at the Fredericton station agreed that the principles of genetics should make it possible "to solve many if not all of the disease problems of potato growers by combining resistance with superior qualities of economic importance".[21] Disease-resistant, freely available public varieties would represent scale-neutral innovations that would reduce production costs and increase security and self-sufficiency of farmers large and small. That optimism sustained the programme through the long years of breeding and screening between 1934 and the programme's first variety release in 1950.

20 H.W. Howard, *Genetics of the Potato. Solanum tuberosum* (London, 1970).

21 H.T. Davies, "Breeding Potatoes for Resistance to Late Blight at the Dominion Experimental Station, Fredericton, N.B." (19 January 1950), in "Davies Papers", p. 6. The claim is quoted from the 1937 *U.S. Department of Agriculture Year Book*. For similar expressions of optimism concerning viral diseases, see R.H. Bagnall, "Hypersensitivity, a Form of Resistance to Plant Viruses in Potatoes", *34th Report of the Quebec Society for the Protection of Plants* (1952), pp. 128-31.

From the Science Service to the Research Branch

Fredericton scientists and administrators were well aware that the potato-breeding programme affected station life profoundly. The programme competed for resources with other lines of agricultural research (usually successfully), and for several decades tended to displace other sorts of potato investigations, such as routine variety tests and cultural and fertilizer trials. In an unpublished report of 1941, Superintendent C.F. Bailey noted that experiments of the latter kind had been largely eliminated and "replaced by projects of a definite research character". Bailey complained that the breeding programme was underfunded by Ottawa, that it drained resources from other work, that it encountered too much interference from supervisory committees outside Fredericton and that it had a tendency to expand its research agendas beyond the capacity of the station.[22] Nevertheless, Fredericton tenaciously defended its national monopoly over potato breeding. The station was officially recognized by Ottawa as the site of the "national" potato-breeding program and, in 1943, over the objections of other stations across Canada, Fredericton was given the exclusive right to develop new varieties of potato seedlings, even if those seedlings were to be transferred to other stations for testing and further development under local conditions. For one programme, at least, the regional mandate envisioned by the station's founders had become a national one.

Like most other forms of agricultural research in Canada, the potato-breeding programme suffered from severe funding cuts after 1939 and during the Second World War but went on to a vigorous recovery in the flood of post-war funding to Canada's science and scientific institutions. Largely because of the national potato-breeding programme and its requirements for scientific personnel, the Fredericton station had emerged by 1960 as Agriculture Canada's largest and best-financed research institution after the experimental farm at Lethbridge and the Central Experimental Farm in Ottawa. Personnel on the experimental farms service side during those years included horticulturalist Louis C. Young, who had come to the station in 1927; H.T. Davies, who joined the potato breeding team in 1946; and D.A. Young who, in 1957, was recruited as the Experimental Farms Service's first specialized plant geneticist. L.C. Young and Davies worked with pathologists and virologists of the Science Service attached to the Plant Pathology Laboratory, notably J.L. Howatt (active at the station from 1930 to 1959), his superior D.J. MacLeod (1924 to 1960) and Scott F. Clarkson (1934 to 1945). The pathologists exposed test-seedlings to pathogens and assessed by visual inspection their degree of resistance. Early on this was done by mimicking field conditions, for example, growing test-seedlings to maturity in rows interspersed with diseased plants. Faster screening methods were developed later and the procedures were moved into the laboratory or the greenhouse. The pathology and virology group expanded rapidly in the late 1940s and early 1950s. R.H. Bagnall came in 1946, C.H. Lawrence in 1948, W.A. Hodgson in 1949, J.P. MacKinnon in 1950 and James Munro in 1951. At the fringes of the breeding programme was Fredericton's

22 "Horticultural Investigations at the Fredericton Experimental Station", 28 August 1941 (five-page ms at the Potato Research Centre library). Superintendent C.F. Bailey's signature appears on the top of the first page.

respected team of aphidologists; key members were Jean Adams, R.H.E. Bradley, Ellen MacGillivray and Pauline Tompkins.[23]

Fredericton pathologists and entomologists achieved much in the 1940s and early 1950s, especially in unravelling the role of aphids in transmitting potato diseases and revealing the nature and complexity of potato viruses. Fredericton horticulturalists also scored major successes with the release of their first two varieties, Canso and Keswick, in 1950. But cooperation among these groups of scientists, in Fredericton as elsewhere, was hampered by administrative structures and competing professional identities. Before 1937, horticulturalists and plant pathologists worked in different divisions of the Experimental Farms Branch, and entomologists in an altogether different branch. After 1937, this administrative separation became even more pronounced when the latter two groups were reorganized into the new Science Service. As noted above, the creators of the Science Service wanted a more theoretical, specialized and professional science that demonstrated a longer-term, less-immediately-practical orientation toward farmers' problems. The old Experimental Farms Branch was the clear loser in this reorganization of 1937, forfeiting responsibilities, budget and facilities to the new Science Service as well as a generous measure of prestige. In the succeeding years, employees of the Science Service, at Fredericton as elsewhere, were more likely to hold degrees in scientific disciplines rather than in general agronomy, to have obtained a Ph.D. and to have published in scientific journals than were employees of the Experimental Farms Service. They also earned higher salaries. The reorganization laid the groundwork for jealousy and turf wars between researchers in the two services, embodying as they did not only institutional rivalries but conflicting visions about agricultural science.

At most of Canada's experimental stations the administrative gap between the two services produced mutual isolation and lack of communication. Fredericton, however, was one of a handful of stations where scientists from the two services had to cooperate on projects like potato variety development that required expertise from both sides of the house. Even there the cooperation was not without recurrent friction, both personal and administrative. Plant pathologists found the mass screening of seedlings required of them for variety development tedious and far removed from actual research; breeders resented their dependence upon other scientific personnel in a programme for which they were primarily responsible. The 1941 memo by C.F. Bailey, cited above, was at pains to convince Ottawa that while the breeding programme was a cooperative project between the station and the Laboratory of Plant Pathology, "most of the work" was done by Experimental Farms Service personnel. The pathologists of the Science Service, Bailey complained, "have been unable to give us the service we require". Both claims served Bailey's plea for more resources and his clear desire to affirm proprietary rights over the breeding project.

By the 1950s a gradual convergence of professional identity seemed to be occurring among scientists of the two services. The Science Service began, for example, to list the scientific publications of its personnel annually in 1947 and to

23 R.G. White, "History of the Fredericton Experimental Station"; I.L. Conners, ed., *Plant Pathology in Canada* (Winnipeg, 1972), pp. 45-51. The publications of all station scientists, and sometimes biographical material, is held in the library of the Potato Research Centre in Fredericton.

distinguish them from extension and miscellaneous papers; the Experimental Farms Service followed suit in 1953. T.H. Anstey's official history suggests that the division of the two services had begun to seem artificial and anachronistic, and that the example of integrated research projects like those at Fredericton may have hastened its end. The new Research Branch, created by Ottawa in 1959 at the instigation of Kenneth Neatby, administratively combined most facilities and projects of the Experimental Farms Service with those of the old Science Service. The reorganization firmly established "research" (no longer "experimentation") as the mission of the branch, tacitly excluded regulatory and extension-related functions from the Research Branch's mission, introduced the problem-focussed organizational philosophy and, at least on paper, decentralized control over research priorities from Ottawa to the various stations and laboratories.[24] The old rivalries persisted long after creation of the Research Branch, but many scientists on both sides of the divide saw the reorganization as affirming a convergence between the research cultures that was already well advanced.

The Limits of Resistance Breeding: Late Blight

The 1950s brought Fredericton scientists up against the hard limits set by nature on the practical efficacy of breeding programmes for disease resistance in potatoes. Those limits were encountered first in the campaign to develop late blight-resistant potato varieties. The first breakthrough in this campaign had come in 1913, when British scientist R.N. Salaman had chanced upon strong late blight resistance in the wild South American species *S. demissum*. By the 1930s, *S. demissum* hybrids were being used in breeding programmes all over the world, with the Dominion Experimental Station in Fredericton among the leaders. By the 1940s, potato geneticists knew that the species possessed as many as four dominant resistance genes, any one of which on transfer to *S. tuberosum* would confer virtual immunity through an intense, hypersensitive reaction. It remained only to make the hybrids, and by means of time-consuming backcrosses restore the desired commercial and agronomic qualities. At the end of the 1940s, scientific optimism about ultimate victory over late blight was strong.

But scientists had not reckoned sufficiently with the genetic variability of *Phytophthora infestans*. Fungi occur in particular strains or races that are often specialized to parasitize particular genotypes of host plant. By the early 1950s seven such strains of *Phytophthora infestans* had been isolated in Europe. The existence of four major resistance genes and multiple strains of the pathogen suggested that an evolutionary, genetic "race" between host and parasite species was occurring in accordance with the so-called "gene for gene" theory. Initially, none of this seemed foreboding. The Scot William Black, then the leading authority in the world, reported optimistically in the 1950s that each of the major genes conferred resistance to the

24 K.W. Neatby, "Impressions Gained in Course of Visits to U.S. Research Laboratories" and "Report of . . . Tour of Research Institutions in the United States . . .", RG 17, vol. 2877, file 12-6-9 (1949), NA; Anstey, *One Hundred Harvests*, pp. 65-76, 85-95. Friction between Fredericton scientists and the Ottawa-based National Potato Breeding Advisory Committee over control of the local breeding program had been recurrent in the 1940s and 1950s. In the 1960s the Fredericton program seemed to have gained greater local autonomy vis-à-vis the national committee.

"common race" of the fungus, and no fungal strain was known that could attack a potato variety into which all four major genes had been introgressed.[25] As late as 1950, no races other than the common race had been identified in Canada.

But the bad news was not long in coming, and scientists at the Fredericton station, along with Maritime potato farmers, bore the brunt of it. A country-wide sampling of fungal isolates carried out from Ottawa in 1952-53 by pathologist K.M. Graham, soon to transfer to Fredericton, identified eight distinct fungal races. Four of them were isolated from the varieties Canso, Keswick, Kennebec and Placid, all of which were recent releases (the first two from Fredericton) carrying late blight-resistant genes.[26] By 1963 Fredericton pathologists Howatt and Hodgson proved that one fungal isolate capable of attacking the resistant varieties had become the predominant race in Eastern Canada on *all* varieties of potatoes, piggy-backing on the success of the supposedly-resistant variety Kennebec. With the discovery of sexually-reproducing, mating groups of the fungus in Mexico, the conclusion seemed inevitable that the fungus could generate continuous new strains in the presence of resistant varieties. Resistance breeding using the major genes could keep scientists one step ahead of the pathogen, but only at the cost of stimulating the rapid development of new, resistant fungal varieties.

The shock and disappointment of this outcome is palpable in the writings of Fredericton pathologists like J. Lorne Howatt, and it proved an embarrassing setback for the station's resistance-breeding programme. Howatt and others were urging by 1956 that the focus be shifted from the major genes conferring race-specific forms of resistance to so-called minor genes that conferred an apparently general resistance effective against all the known races. Being recessive and effective only through the action of more than one gene, however, the minor genes were far more difficult to study and transfer in the tetraploid *S. tuberosum*. The other response was to go beyond *S. demissum* to seek new sources of resistance in the many wild, diploid Mexican species, only a few of which had been studied by the early 1950s. The wild Mexican diploids are notoriously self-sterile, and the limited fertility of them and their progeny posed significant problems for crossing with *S. tuberosum* as well. The attack on these problems carried breeding work in Fredericton and elsewhere to a new level of genetic complexity and manipulatory sophistication. It was begun by a younger generation of biologists and geneticists, including Leo A. Dionne, K. M. Graham, James Munro and O.T. Page, assisted by new techniques for manipulating ploidy that emerged in the 1950s and early 1960s.

For the potato industry as a whole, this setback shifted efforts toward controlling late blight through increased reliance on chemical fungicides rather than biology and

25 William Black, "Inheritance of Resistance to Blight (*phytophthora infestans*) in Potatoes: Inter-Relations of Genes and Strains", *Proceedings of the Royal Society of Edinburgh*, series B, vol. 64 (1952), pp. 312-52; H.H. Flor, "Inheritance of Pathogenicity in *Melampsora lini*", *Phytopathology*, 32 (1942), pp. 653-9; H.H. Flor, "Host-Parasite Interaction in Flax Rust", *Phytopathology*, 45 (1954), pp. 680-5; Clayton Person et al., "The Gene-for-Gene Concept", *Nature*, 94, 44828 (12 May 1962), pp. 561-3; L.C. Young and H.T. Davies, "The Nature and Inheritance of Resistance to Late Blight Phytophthora Infestans Mont. De Bary", a presentation to a seminar group at the Dominion Experimental Station, Fredericton, N.B. (25 March 1954), "Davies Papers", pp. 77-88.

26 J.L. Howatt and W.A. Hodgson, "Testing for Late Blight Resistance in the Potato in Canada", *American Potato Journal*, 31, 5 (1954), pp. 129-40.

genetics. New chemical products emerged to replace the traditional, copper-based Bordeaux mixture.[27] But these were preventive fungicides, which required application in advance of a suspected infection and were powerless to eradicate an outbreak once established. How often and how early a grower should spray, therefore, became largely a function of what expense he could afford and what degree of risk he was prepared to run. To impose some predictive rationality on this decision-making process, some station scientists were redeployed to the provincial government's new late blight-forecasting programme to develop models for forecasting crop loses and rationalizing spray schedules.

The real importance of these developments can only be seen in a larger context. Throughout the 20th century, North American farmers grew steadily more dependent on off-farm inputs of materials, labour and energy. This process made possible sustained increases in yields, but it also imposed higher production costs and capital requirements on farmers. That, in turn, resulted in pressure toward economies of scale, growing debt loads and a cost-price squeeze that drove many smaller producers off the land. Potato agriculture in New Brunswick provides a dramatic regional illustration of this relentless dynamic. Thomas J. Murphy demonstrated that the 1950s and 1960s were the key decades in a rapid concentration of New Brunswick potato production onto larger farms located in the "potato belt" counties of Carleton, Madawaska and Victoria. In 1951 there were 20,004 New Brunswick farms producing 38,123 acres of potatoes; in 1966 there were 5,471 farms producing 65,000 acres. Over the next 15 years many factors, among them the impact of the mechanical harvester, would reduce the number of potato farms to 740 and bring about a six-fold increase in the average number of potato acres per farm.[28]

This dramatic structural transition was due, in large part, to the growing capital requirements of competitive potato farming; nature's refusal to permit the ready development of truly effective blight-resistant varieties was one factor among the many that stoked the new capital requirements. In the 1920s best-practice was recommending four or five fungicide applications per season to New Brunswick potato farmers; by 1960 the norm on New Brunswick farms was eight to nine applications, plus top-killing before harvest. Although absolute outlays per acre for chemical sprays rose dramatically, fungicides' portion of production costs per acre actually fell, from about ten per cent in 1925 to less than five per cent in 1960, confirming growers' chemical dependency.[29] Fungicide-based management practices controlled late blight effectively and contributed to gradually expanding yields for farmers who could afford them. They also made potatoes the most chemical intensive of the major field crops on a per-acre basis, and today a sustainable balance between genetic resistance and chemical control measures is still being sought.[30]

27 Ainsworth, *History of Plant Pathology*, pp. 108-13, 120.

28 Thomas R. Murphy, "The Structural Transformation of New Brunswick Agriculture from 1951 to 1981", M.A. thesis, University of New Brunswick, 1983, esp. pp. 1-37. See also Darrel A. McLaughlin, "Beyond the Farm Gate: A Case Study of Constraints and Possibilities as Experienced by New Brunswick Farm People", M.A. thesis, University of New Brunswick in Fredericton, 1993.

29 Experimental Station, Fredericton, N.B., *Report of the Superintendent . . . for the Year 1925*, pp. 28-35; *Royal Commission on the New Brunswick Potato Industry*, pp. 92-9, 16-7.

30 On the resistance versus control issue today see G.R. Mackay, "Basic and Applied Reserch Needs for Sustained Crop Health of the Potato", *American Journal of Potato Research,* 77 (2000), pp. 334-8.

The Limits of Resistance Breeding: Viral Diseases

Even more significant for the industry were the hard realities that awaited scientists in their struggle with viral diseases. As late as 1920 the exact nature of viral agents was uncertain and controversial, but that did not prevent plant pathologists from distinguishing and identifying viruses on the basis of the symptoms they induced in plants of various species or the means by which they could be transmitted. This was a labourious, greenhouse-based science that involved transmitting a virus or combination of viruses through a complex sequence of indicator hosts in order to isolate and identify it. Nevertheless, between 1920 and 1940 some 17 viral diseases of the potato, and all the major ones known today, were identified. Scientists learned that aphids spread some of the most serious potato viruses and that particular combinations of viruses produce disease symptoms unlike those produced by any virus alone.[31] By the 1940s it was clear that viral infections of potatoes cannot be wholly prevented under normal field conditions; that virtually the entire crops of most potato varieties are infected with latent viruses and that viral diseases are a major limitation on potato production.

But what to do about it? The most direct technological response was to develop varieties of potato resistant to the various viruses. The Fredericton breeding effort committed itself strongly to that program, partly because of soaring aphid populations during the 1940s that made virus infections increasingly common across the province. The so-called mild mosaic (PVA) and the more serious leaf roll disease, both transmitted by aphids, received special priority in Fredericton's early resistance-breeding program. Around 1950, when it appeared that DDT had effectively controlled the aphid population and, with it, leaf roll disease, attention shifted to the viruses A, B and C and especially to the latent virus X. Efforts to breed for virus resistance further shifted scientific expertise out of the field and into the laboratory as well as from one set of scientific specialists to another, as serological or grafting tests replaced visual inspection in screening clonal selections.[32]

In Fredericton, pathologists Roy Bradley, J.P. Mackinnon and R.H. Bagnall led the work on potato viruses, aphid-vectors and methods of controlling them, and their efforts produced significant victories and recurrent frustrations. R.H. Bagnall, for example, showed that DDT spraying, so effective against resident populations of aphids that transmitted leaf roll disease, had little effect on the transient populations of aphids that produced the virus Y. This demonstration, however, did little to blunt the enthusiasm of producers and extension personnel for DDT and other insecticides.[33] The search for germ plasm on which to base new viral-resistant cultivars led Fredericton breeders back to old varieties like Irish Cobbler, to newly developed British and American lines and to Dutch varieties developed from wild

31 D.J. MacLeod, "The Identification of Potato Viruses", *Report of the Quebec Society for the Protection of Plants, 1952-57*, 34 (1958), pp. 87-95; Ainsworth, *History of Plant Pathology*, pp. 82-6; Sally Smith Hughes, *The Virus: A History of the Concept* (London, 1977).

32 L.C. Young and H.T. Davies, "Potato Breeding at the Fredericton Experimental Station", (seven-page 1951 ms at the Potato Research Centre library).

33 R.H. Bagnall and J.P. MacKinnon, "Count-Down on the Potato Viruses", *Canadian Agriculture* (1962), pp. 8-9.

South American species, but the work produced mixed results and necessitated significant tradeoffs. Keswick, released in 1950 as the Fredericton station's first late blight-resistant variety, was known at the time of its release to be very susceptible to virus X.[34] Modest successes notwithstanding, the number and diversity of potato viruses made it unlikely that resistance breeding would be capable of producing varieties possessing broad resistance against most viral diseases.

The limits on what viral resistance breeding could practicably achieve drove producers to depend increasingly upon improved phytosanitary measures and more rigorous certification standards to ensure the maintenance of virus-free stocks. G.C. Cunningham had been New Brunswick's early champion of such measures. In the interest of disease-free stocks, quality maintenance and healthy bottom lines, farmers were urged to maintain separate seed potato beds, rogue them assiduously, sterilize instruments and equipment and plant only certified seed. By the 1950s the federal Seed Potato Certification Service (also headquartered on the Dominion Experimental Station grounds in Fredericton) was recognizing a small group of elite provincial growers who alone were entitled to produce and multiply new, relatively clean foundation seed stock. The Certification Service extended to these growers the opportunity to have their best selected tubers tested, first against the very serious bacterial disease ring rot, and then against latent viruses, before being multiplied in the fields for sale as certified seed stock.

Researchers at the Fredericton station assisted the province in the development of its phytosanitary system. The station initially provided facilities and expertise for greenhouse screening of seedlings and tubers in winter grow-outs and, by the 1970s, was exploring techniques for obtaining disease-free "nuclear" stocks. Virologists purified viruses and developed sensitive, high-titre antisera to many of them in order to improve serological tests for infected plants and tubers. Responsibility for the technical aspects of the phytosanitary system, however, was gradually assumed by the federal Plant Protection Service and by New Brunswick provincial authorities. In 1966 New Brunswick opened the provincially owned Bon Accord Seed Farm, which thereafter became the main source of new, "elite" seed for provincial growers.[35]

The real significance of the phytosanitary system can best be seen from a comparative and theoretical perspective. As noted, North American agriculture in the 20th century experienced remarkable, sustained increases in yields and productivity, accompanied by producers' growing dependence on off-farm inputs of energy, fertilizers and agrochemicals. This growing dependence has often been taken to illustrate how scientific research furthers the penetration of capitalist, commodity production into agriculture, even while the farmer himself remains nominally an independent, propertied producer. In his 1988 seminal study, Jack Kloppenburg Jr. extended this analysis, maintaining that, for most major crops, seed had also become an off-farm input, purchased in the market rather than saved from the previous year's crop. This development, he argued, had been brought about through the breeding of

34 *Research Report* Dominion Research Station (Ottawa:1958-1960, 1961-62, 1963-64).

35 Department of Agriculture of the Province of New Brunswick, *Annual Report* (1950-1975). In 1975, for the first time, all seed sold by the provincial seed farm to growers for multiplication was virus-free.

hybrid crop varieties, whose seed was high yielding but had to be purchased anew each year from seed companies. Combined with the extension of Plant Variety Protection and Plant Patenting acts, this practice was responsible for the "commodification" of seed and the development of a capitalist seed industry, and contributed to the growing subjugation of farmers to market forces beyond their control.[36]

New Brunswick's experience with seed potatoes offers a revealing variation on the Kloppenberg model. Seed potatoes in New Brunswick, as elsewhere, underwent a commodification, but the resulting seed-supply system was scarcely capitalistic, has made little use of proprietary varieties to date and owed its origins less to direct market forces than to government-enforced phytosanitary measures. In New Brunswick, as in other Canadian provinces, the introduction of the federal Seed Potato Certification Service was accompanied by provincial legislation making it illegal to sell non-certified tubers as seed, even though planting non-certified seed saved from last year's crop or one's own seed plot remained a legal, common practice. Federal standards for certification became increasingly rigorous decade by decade, progressively narrowing the proportion of growers able or willing to reproduce their own certified seed and rendering producers who wished to plant certified seed more dependent upon seed purchases from beyond the farm. In 1970 the federal government formally introduced the Elite Production System with its "flush through" provision, by which no potatoes could be qualified for certification at any level if they were more than five generations removed from uninfected initial stock. Finally, New Brunswick provincial legislation in 1979 banned the planting of non-certified seed for any purpose, eliminating the growers' right to save seed except from inspected and certified fields.[37] At this point "seed" was redefined to mean "government certified seed" and the commodification process was almost complete.[38]

Kloppenburg argues that agricultural research contributed to the commodification of seed in many major crops. This paper suggests that rather the opposite was true for potatoes – that commodification was a response to the inability of scientific breeding to produce new varieties that were simultaneously disease resistant and able to achieve widespread adoption by growers. But scientific research did open up alternatives to disease resistance by making it possible to produce popular, older varieties in virus-free forms. The system's later development, especially its goal of totally virus-free nuclear stock, depended heavily on research breakthroughs in

36 Jack R. Kloppenburg, Jr., *First the Seed. The Political Economy of Plant Biotechnology 1492- 2000* (Cambridge, 1988), pp.1-49. See also Frederick H. Buttel, *The Rural Sociology of Advanced Societies: Critical Perspectives* (Montclair, NJ, 1980) and Murphy, *Structural Transformation of New Brunswick Agriculture*, pp. 10-37.

37 The key legislation is the federal *Seeds Act* (and accompanying regulations) and the New Brunswick *Potato Disease Act* (1969) as well as the *Potato Disease Eradication Act* (1979)*, Revised Statues of New Brunswick*, ch. P-9. See also Canadian Food Inspection Agency, *Seed Potato Certification Manual* (May 31, 2002), ch. 1: "Background and Policy" and Scott F. Clarkson and Grace A. Olts, *History of Potato Industry Legislation in New Brunswick*: *Fifty Years of Progress 1914-1963* (Fredericton, 1963).

38 Full commodification would require patent-protected varieties with further restrictions on the "farmers' privilege" of saving seed, a development possibly portended in genetically-modified varieties.

detecting viruses and creating virus-free plants through heat treatments and meristem technology. The phytosanitary system that grew out of these technologies was very effective in reducing the role for regional potato producers as it represented a significant regulatory intrusion into the activities of potato farmers; it does not seem, however, to have been much resisted or resented by New Brunswick growers.[39] On the other hand, the pressure of international competition clearly drew regional producers into conditions of capitalist dependence, and the phytosanitary system was developed more as a tool in that competition than in response to disease per se. States and provinces were all too ready to use disease threats, real or imagined, to block imports from competitors and to tout the superior cleanliness of their own exports in foreign markets. In this way, international trade rivalries created strong competitive pressures toward the development of broadly similar phytosanitary systems, comparable certification standards that grew ever more rigorous over time and the similar bodies of technical expertise needed to sustain both.[40]

Potato Science, the Potato Industry and New Research Directions

While the impact of potato science on long-term structural trends in New Brunswick farming was profound, research agendas at the station, to a significant degree, reflected as well as influenced the social and political context of New Brunswick agriculture during the 1950s and 1960s. In this period, competition intensified, especially in the lucrative foreign market for seed potatoes, and it brought new pressure for economies of scale, organization among growers and new, more efficient marketing mechanisms. These structural changes benefited a few producers, drove many others out of potato farming altogether and increased levels of farm debt.[41]

The emergence of the potato-processing industry was fundamental to this transition. The three potato chip companies located in New Brunswick since 1945 had

39 But there may have been some resistance. The province's decision to establish Bon Accord Farm was motivated partly by the conviction that earlier legislative measures to establish restricted seed stock areas were proving unenforceable. See Anon. [Scott F. Clarkson?], "Production of Disease-Free Certified Seed Potatoes", 1960, Potatoes/potato starch 1960-1965, RS 124, B20a4, PANB. The annual reports of the Fredericton station show seed amounting to 20 to 25 per cent of total production costs per acre in the 1920s, the *Report of the Royal Commissin on the New Brunswick Potato Industry* showed them at 14 per cent of total production costs in 1959-60 (pp. 100-1) and rough estimates for the late 1990s suggest 10 to 20 per cent depending on the quality and variety of the seed purchased and sown.

40 The phytosanitary system and the commodification of seed potatoes may also have been one minor factor contributing to the fragmented and fractious nature of the potato industry in the Maritimes, a circumstance that has made it difficult for regional potato growers to organize and cooperate in protection of their market interests. The system accentuated the differences between seed and other producers and may have fragmented the seed production sector by creating hierarchies of access to new elite seed stocks. In turn, the industry may have been left more vulnerable to market forces beyond the region. On the fragmentation of the potato producers' community in New Brunswick see *Report of the Royal Commission*, pp. 195-204, and government-driven efforts to organize the producers are chronicled in annual reports of the Department of Agriculture of the Province of New Brunswick, 1962-1990. For a comparison with the PEI industry, see *Report of the Royal Commission on the Prince Edward Island Potato Industry*, vol. 1 (November, 1987), pp. 16-81.

41 Murphy, *Structural Transformation of New Brunswick Agriculture*, esp. pp. 1-37.

really generated little demand for tubers, but the opening of the McCain french fry plant in Florenceville in 1956 changed the face of the industry in the province. In 1956 processing took only 6 per cent of New Brunswick's total potato production, but by 1961 the proportion was up to 15 per cent and would reach nearly 40 per cent in 1971. The McCain presence subjected farmers to the enormous market power of a near monopsony. McCain pursued an active policy of vertical integration and diversification through subsidiaries, not only selling potato seed, chemicals and harvesters, but also purchasing farmland, so that by 1976 the company was growing seven per cent of all New Brunswick potatoes. The firm also introduced contract growing to New Brunswick, a practice which brought producers some degree of security in the notorious boom-and-bust potato market, but also subjected their farming practices to intense external control, since the contacts closely stipulated the variety and quality of seed to be used and the fertilizer and pesticide schedules to be observed.[42]

The 1950s and 1960s also witnessed shifts in provincial and federal government policy toward farmers. The Agricultural Rehabilitation and Development Act of 1962 and its various federal-provincial successor programmes all sought to promote economic development in rural areas by linking primary- and secondary-sector development. For agriculture, this usually meant re-defining farm production as one link in an extended "agri-food" or "food production" system that would in practice be dominated by the needs of secondary producers in the interest of value-added production. Although state initiatives during this period sought to reduce farmers' risks through programmes of crop insurance, commodity price supports and marketing boards, these were usually accompanied by insistence on the need to rationalize and modernize the farm enterprise and sometimes by open hostility toward small, "inefficient" and under-capitalized operations. Rhetorical defences of the family farm continued to flourish in government pronouncements, but increasingly these defences were extended only to family farms deemed viable and rational.[43]

Nowhere was this philosophy more clearly on display than in the Report of the Royal Commission on the New Brunswick Potato Industry, commissioned by the New Brunswick government in 1960. In alarmist tones, the Report concluded that "all is not well with the New Brunswick potato industry". Not only had production fallen behind that of Prince Edward Island, but the Report described the industry as threatened by a "disastrous complacency" which was leading it to ignore what the Commission described as a revolution in potato growing going on elsewhere. New Brunswick's principal problem, in the view of the Commission, was that "very few potato acreages . . . are sufficiently large to sustain a reasonable annual return to the grower", since to be efficient any producer must have access to "upwards of $20,000 of working capital each season". Present methods of short-term financing had the

42 Murphy, *Structural Transformation of New Brunswick Agriculture*, pp. 152-93. Murphy argues that these developments effectively "proletarianized" potato producers (p. 184), an interpretation challenged by Kloppenburg and other members of the Cornell group.

43 See Murphy, *Structural Transformation of New Brunswick Agriculture*, pp. 194-222; Donald J. Savoie, *Regional Economic Development: Canada's Search for Solutions* (Toronto, 1986), pp. 11-32 and (for the modernization ethos at work in another primary resource industry) Miriam Wright, *A Fishery for Modern Times* (Don Mills, 2001), pp. 37-61.

advantage that they "discourage small or inefficient producers" but the disadvantage that they "undoubtedly prevent the consolidation of larger potato enterprises". Of the four areas covered by the Commission's mandate – research, production, marketing and processing – the Commissioners insisted that too much energy in the past had been devoted to research and production concerns, too little to marketing and processing.[44]

These developments meant that the Fredericton station was now pursuing its breeding programme in a different economic and political environment. The growth of the processing industry accentuated a phenomenon already established in the tablestock market, namely, the power of large end-use buyers to determine the varieties that farmers planted. Advanced varieties developed by scientific breeding faced reduced chances of widespread adoption by farmers, since large buyers had less to gain from disease-resistant or higher-yielding varieties than direct producers and so generally preferred established, older varieties despite their known liabilities. On the basis of its excellent qualities for fry-manufacture and its widespread promotion by McCain, the old variety Russet Burbank (regionally known as Netted Gems) emerged from obscurity in the 1950s to become one of the most-planted potato varieties in New Brunswick by 1975, despite its alleged tendencies to knobbiness, lateness and relatively high degree of disease susceptibility. On the other hand, new uses for potatoes and a more differentiated market for tablestock presented challenges to breeders to create varieties with desirable processing qualities and appeal to specific markets. In 1962 the Royal Commission took no notice at all of the continuing efforts of the Fredericton station toward disease resistance. It did, however, praise the station's development of varieties introduced during the 1950s as offering New Brunswick growers the opportunity for market flexibility and rapid adaptation to niche markets.[45]

In the new political and commercial climate of the 1950s, calls began for the Fredericton station's research to become more practically oriented and market conscious, usually with the implied criticism that these concerns had been neglected previously. In 1958 the Canadian Horticultural Council called upon the federal government to reorient potato research toward product utilization, potato quality and quality testing, and marketing practices. In 1959 the New Brunswick government urged the federal government to create a "Potato Research Institute" in Fredericton, a body that would concentrate on the search for "practical solutions to all important potato problems". Harrison McCain, in a letter to the New Brunswick government in 1969, criticized what he considered to be the federal institution's overcommitment to pure research on potato problems and urged a turn to practical investigations like

44 *Royal Commission on the New Brunswick Potato Industry*, pp.1-46.

45 *Royal Comission on the New Brunswick Potato Industry*, pp. 73-5; Murphy, *Structural Transformation of New Brunswick Agriculture*, pp. 99-101.

46 S.F. Clarkson to R.D. Gilbert, May 12, 1958, Plant Protection and Promotion Branch – Corresp., 1938, 1958, 1960 and 1962, RS 124, F6b, PANB; S.F. Clarkson, "Potato Brief: An Up to Date Potato Program for the Province of New Brunswick", October 1958, Plant Protection & Promotion Branch: Potato-general, 1943, 1956-1960, 1967, RS 124, F6c1, PANB; Harrison H. McCain to Hon. J. Adrien Levesque, 3 March 1969, Potatoes: McCain, 1964, 1967-71, RS 123, B9F, PANB; *Royal Commission on the New Brunswick Potato Industry*, 1962.

those which, in his view, had produced canola.[46]

These calls for new research priorities mirrored a redirection of research that was going on within the Fredericton station itself. During the 1950s the breeding programme's objectives were being gradually broadened to include an improvement of agronomic quality, with new attention to the taste and starchiness of tubers. In 1951 the station opened its first cooking laboratory, under H.T. Davies, to compare the culinary properties of different varieties. New releases were increasingly targeted to specific market niches and understood as discreet packages that possessed specific combinations of agronomic characteristics, management requirements and disease resistances and susceptibilities. These included the development of netted-skin varieties for Western Canada, purple-skinned and wart-resistant varieties for Newfoundland and red-skinned types for certain export markets. But local needs also figured heavily in the station's research agenda. By the mid-1950s Fredericton breeders had begun to focus on the needs of the newly emerging chipping industry; by the late 1950s they had begun to address what provincial politicians hoped would be a New Brunswick potato starch industry; and by the early 1960s they had launched variety development for the french fry industry. External calls for a more practically oriented and market-conscious research agenda therefore mirrored, and on occasion may have appeared at the instigation of, like-minded elements within the station itself.

This broadening of breeding objectives was tacitly premised on the assumption that disease resistance alone would not ensure a new variety's adoption by growers. Some Fredericton scientists who had spent their careers in the development of disease resistance found this outcome unexpected and frustrating. In 1954 virologist James Munro acknowledged with some annoyance that growers were often prepared to ignore or tolerate virus infections, and that they were not much interested in new, resistant varieties that would displace their familiar and commercially proven cultivars. Given this frustrating frame-of-mind among growers, he wrote, there was no other course open to scientists than to "clean up" the traditional varieties and make sure that they were available in virus-free forms. As for variety-development work, scientists would have to face the hard fact that resistance would take second place to agronomic qualities if new varieties were to attract support.[47]

Despite the agreement that agronomic improvement and disease resistance must now coexist as development objectives, achieving the proper balance between these goals seems to have created continued friction among station scientists. In particular, it seems to have pitted potato breeders, who championed an expansion of breeding objectives, against cooperating pathologists, who felt that the long-term potential for genetically-resistant varieties was being prematurely discounted in the process. In this way, friction within the breeding programme continued to reflect the older alignments between scientists of the Experimental Farms Service and those of the Science Service. Disagreement expressed itself less in formal debates over priorities and policies than in the hundreds of small, recurrent screening decisions – at that time made collectively by breeders, pathologists and entomologists – about whether the

47 James Munro, "Maintenance of Virus-Free Potatoes", *American Potato Journal*, 31, 3 (March 1954), pp. 73-82; James Munro, "The Importance of PVX", *American Potato Journal*, 38, 12 (December 1961), pp. 440-7.

characteristics of a particular seedling qualified it for further testing, backcrossing and observation, resulting in either multiplication or elimination.

By 1965 retirements, resignations and transfers had depleted the ranks of the station's pathologists and breeders, and with a major turnover of scientific personnel pending, the station undertook a review of its potato-breeding programme, and its objectives. Some decisions taken after the review formalized or consolidated new directions already in place: to further exploit new germ plasm sources from the wild and cultivated diploid species and the tetraploid *andigena* subspecies; to hire new personnel skilled in the utilization of these genetic resources; to expand breeding objectives to meet the needs of the processing industries; and to recognize that successful new varieties must combine agronomic characteristics and disease resistance in combinations tailored to particular markets. The most controversial decision reached in the review was to reduce the size of the breeding programme's local steering and evaluation committee and restrict it primarily to breeders. This step essentially transferred authority away from the collectivity of scientists cooperating with the potato-breeding programme to lodge it with the breeders themselves. A decision was also reached to appoint a pathologist directly to the potato-breeding section to take over the routine screening entailed by the work.

Collectively these decisions of the mid-1960s ratified a shift in program philosophy as fundamental as that which had marked the launch of the breeding programme in 1934. In the process, however, little had to be abandoned or sacrificed. The infusion of money into Canada's public research capacity that began in the 1950s made it possible for public-sector agricultural scientists to expand their research agendas on all these fronts. By 1970 the station's potato research was broader and more diverse than it had ever been, embracing variety development, plant physiology, plant pathology and disease control, and cultivation and management studies.

But in the process the station and its research programs had changed. After 1959, as had been intended by Neatby in his creation of the Research Branch of Agriculture Canada, the investigations carried out by the Fredericton station became increasingly specialized, technical and intensive. Station scientists were increasingly prepared to describe their work using interventionist and engineering metaphors foreign to the scientific prose of the earlier part of the century. Louis C. Young, head of the breeding project, noted as early as 1958 that the trial-and-error methods of previous decades had given way to "advanced scientific approaches" that probed causal mechanisms as well as phenomenal effects. By 1973 his successor, D.A. Young, was prepared to describe his team's work as "trying to rebuild a species".[48]

With that gradual change in research style, the role of the station in New Brunswick's agricultural community was also altered. By the 1950s the responsibility for farm extension work was being increasingly assumed by the New Brunswick provincial government or other federal agencies. The station closed its network of illustration stations in 1956; production economics mostly disappeared from the station's bulletins and annual reports; field days and open houses declined in attendance and significance; and research specialization gradually replaced the station's original mixed-farming focus.

48 *Maritime Farmer and Cooperative Dairyman*, 2 September 1958, p. 3; 6 February 1973, p. 12.

Conclusion: Potato Science, Potato Agriculture and Two Theoretical Problems

This study of agricultural science in one regional centre sheds light on two theoretical disputes within the social studies of science. One of those disputes has focussed on "social constructivist" interpretations of scientific change. Social constructivist accounts privilege institutional context, the interpersonal dynamics of the research community and the influence of the larger socio-political milieu as causal factors of scientific developments. In doing so they have provoked bitter protests that "nature", in the sense of objective empirical discoveries, has been abandoned as an explanatory determinant of scientific change.

This story of potato resistance breeding shows how both sorts of factors – nature and society – were inextricably bound together. On the one hand, the evolution of potato research in Fredericton demonstrates how viruses and fungi frustrated the earlier, optimistic hope that resistance breeding would provide universally accessible, relatively cost-free solutions to the farmers' need for disease control in potatoes. Nature's frustration of that research agenda helped turn the industry toward different solutions and different types of scientific expertise, including increased reliance on fungicides and the construction of a state-enforced phytosanitary system. Those new solutions contributed in distinct if limited ways to a much larger structural transformation of potato farming and the potato industry, which was widespread in the region during the period 1950 to 1970.

On the other hand, this story has also shown that beyond factors related to viruses and fungi, scientists, civil servants, Royal Commissioners, entrepreneurs, economists and politicians worked to promote new research agendas for potato science and potato breeding. The kinds of social factors that shaped these scientific outcomes were partly institutional and professional, but they were also partly economic and political. The waves of rationalization and consolidation that swept through regional agriculture in the 1950s and 1960s not only brought deep structural change to the potato industry, but also exerted powerful pressures to refocus the agenda of scientific agriculture from the exclusive needs of producers to the needs of the industry.

A second theoretical issue of interest to the social studies of science concerns the interpretive gap that often seems to loom between the supposed universality of scientific knowledge claims and the ineluctably local and particularistic contexts in which that knowledge is produced and subsequently shaped. This study both illustrates that tension and in part dissolves it. The scientific developments traced here at the Dominion Experimental Station in Fredericton closely parallelled those going on in other research facilities and breeding programmes across North America and Europe at the same time, just as the structural transformation of the New Brunswick potato industry broadly mirrored similar developments elsewhere in the region and in other potato-producing areas of North America. Despite its national mandate and the trans-regional nature of its breeding programme, however, provincial and regional needs and pressures acted strongly upon the Fredericton station and its personnel throughout its history. Station scientists interacted with regional producers, processors and provincial officials in setting breeding objectives and in devising strategies against disease; at the same time, from the initiation of the breeding programme in the 1930s to the broadening of its objectives in the 1950s and 1960s, regional needs and pressures mediated indispensably between local programmes and international developments in potato science. In the potato-breeding programmes of the Fredericton station, there was no conflict between the supposed universalism of science and the specifically regional and provincial context in which it was pursued.