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# A Maturing of Purpose:
## Recent Publications in the History of Technology and the Physical Sciences in Canada

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themselves. It is now also rare to find any scholar writing Native history who is not familiar with anthropological concepts. The nature of egalitarian band societies, the phenomenon of revitalization movements, the integral world view of hunter-gatherers who do not make a distinction between the human domain and the rest of the world, these are now understood by historians as well as anthropologists. For their part, anthropologists are now increasingly sensitive to the context and reliability of historical documents. Historians have less and less need to complain about the tendency for anthropologists to regard all historical sources as being equal in validity, to rely on imperfect translations, and similar sins. Perhaps most importantly, all researchers engaged in the writing of Native history are concerned about the phenomenon of racism, both in themselves and in the sources they consider. Anyone in doubt of this should read a sampling of Native histories dating to 30, or even 20, years ago. There will always be room for improvement, of course, but the problem has been recognized, thanks to pioneers such as Bailey and Trigger, and it is possible to be optimistic for the future.

RALPH T. PASTORE

## A Maturing of Purpose: Recent Publications in the History of Technology and the Physical Sciences in Canada

IN 1899 G.M. DAWSON, Director of the Geological Survey of Canada, wrote Edwin Gilpin, Inspector of Mines for Nova Scotia, to suggest that the province not contribute machinery for the forthcoming Paris International Exhibition but restrict itself to sending mineral specimens. There would be little interest in exhibits by Canadian-owned manufacturers of mine machinery. After all, he remarked, "everything here is made on foreign patterns or by branch establishments".[1] Dawson's attitudes were typical of his time. In science many Canadians saw themselves as poor relations internationally; in engineering, Canadians borrowed happily from their British and American peers, consistently drawing upon foreign sources. Though much changed in specifics, belief in Canadian inferiority and dependency in science and technology survives today in contempor-

1 George M. Dawson to Edwin Gilpin, 28 April 1899, vol. 20, RG 21, Series A, Mines and Mining Collection, Public Archives of Nova Scotia.

ary Canadian attitudes, recently described as an instance of "negative myth-making".[2] One consequence of the "myth" has been a general lack of interest in tracing the development of Canadian science and technology — even where science and technology have profoundly influenced Canadian culture and economic growth. Recently, however, and with less fanfare than has been evident in other, more politically charged fields such as labour history and women's history, two new, closely-related fields have emerged: the history of technology and the history of science in Canada. A new association, the Society for the History of Science and Technology in Canada, was founded in the mid-1970s and has published a journal, *Scientia Canadensis* (formerly the *HSTC Bulletin*), since 1976.

What has animated interest in the history of science and technology in Canada? Nationalistic sensibilities are sometimes an answer as historians rediscover Canadian contributions in science and technology; with others, a more detached appreciation for the importance of science and technology within larger historical processes predominates. Recurrent threads within much of the writing are an intellectual preoccupation with the complex interactions between science and technology and the social, cultural, and economic environment; an interest in the processes by which scientific understandings of the physical world and human society have emerged; and a fascination with the radically distinct views of nature often present in early scientific and technological thought. So far there has been little conscious historiographical debate and, especially in the history of technology, few more distinct "grand themes" have emerged — merely the beginnings of what may become leading concerns.[3]

History of science and technology is nevertheless rapidly maturing. Despite the relative infancy of research, three young historians, Luc Chartrand, Raymond Duschene, and Yves Gingras, have already published a coherent, balanced, and perhaps surprisingly comprehensive survey of the *Histoire des sciences au Québec* (Montreal, Boreal, 1987). This thoroughly intelligent book traverses the field from idiosyncratic 17th century French perceptions of Canadian fauna, to Ultramontane participation in Darwinian debates of the 19th century (less significant than might have been supposed), to French-Canadian and English

2 Scott Tiffin and Mary Wallis, "Negative Myth-Making: Canada's Self-Image and its Implications for Scientific and Technological Development", *Journal of Canadian Studies*, XXIV (Spring 1989), pp. 32-49.

3 As indicated by various of the books under review here and by other recent publications, several of the leading interests currently within history of technology are the institutional basis of innovation, the influence of technology on the work experiences of labouring classes, and technological transfer (the systematic exploitation of imported technology and its adaptation to the Canadian situation).

Quebec research in physics in the 20th century. In this moderately revisionist history, the authors have set out to assess French-Canadian and English-Canadian contributions in science with no preconceived assumptions of inferiority. Gingras, Duschene, and Chartrand believe that, despite popular belief, the Catholic church in Quebec has normally been supportive of science; in fact, until World War II the most eminent French-Canadian scientists were generally also members of the clergy. The Quiet Revolution, they argue, owed much to a "movement scientifique" which began in the 1920s and stressed technical and scientific education, popularization of science, participation of intellectuals in politics, expanded research, and the promotion of French-Canadians in scientific careers (especially through nationalization of natural resources).

Chartrand, Gingras, and Duschene are not alone in seeking to understand the place of science in larger historical processes. Other young historians are also using research in the history of science and technology to address familiar issues within Canadian historiography. Scientific and technical themes are becoming integrated within mainstream Canadian historiography; they are swiftly becoming more serious subjects of research. Yet analytical depth has been long in coming. Considerable energy has been expended in long-winded attacks on the popular perception that, historically, Canadian science and technology has been primarily imposed or borrowed wholesale and that there has been no tradition in Canada of indigenous "Canadian" accomplishment. Nationalist preoccupations have directed much of the historiographical agenda towards self-conscious efforts to *prove* the existence of a "Canadian" science and technology. This has been an intellectually sterile goal except where the emphasis has been on setting indigenous development and scientific and technological transfer in their precise economic and cultural relationships. Where *some* compensating virtues have appeared have been in efforts to isolate peculiarly Canadian characteristics in science and technology.

Doris H. Jelly's *Canada: 22 Years in Space* (Ottawa, National Museum of Science and Technology, 1988), a frankly uncritical chronicling of Canadian achievements in space research, illustrates some of the pitfalls of writing by authors new to the field of history. Jelly endeavours to show how Canadians acquired the industrial capacity and knowledge that permitted Canadians to "exploit the potential of spacecraft in areas specifically related to Canadian needs and the Canadian environment" and allowed Canadians to become "world leaders in the fields of satellite communications, earth observations, and space science" (p. xi). Jelly has been a research scientist with the Canadian space program for most of her professional life. While the book was planned to provide only the "skeleton" of the story (p. x), it is unfortunate that more was not attempted. It is particularly regrettable that familiarity with her field has not led Jelly to more telling insights into the internal dynamics of Canadian space research, its protagonists, its precise political, cultural, and economic contexts, and the inevitable blind alleys into which Canadian space research blundered

(Jelly's account is a bit Whiggish). Unfortunately, like many, although by no means all scientists turned historian, Jelly betrays limited reflective sensibilities, concentrating instead on flat narratives of names and events and institutional involvements.

The book nevertheless provides a coherent account of the more important developments in Canadian space research and a clear sense of the more obvious features of the Canadian space program. In time-honoured Canadian fashion, Jelly views climate and geography as having been crucial in guiding Canadian development. Early research was pure science, devoted largely to studies of the upper atmosphere, but the launch of the Alouette I satellite in 1962 became the foundation for subsequent achievements in remote-sensing and communications satellites. Notably, the design of Alouette I embodied an inherently conservative bias towards longevity and reliability. This bias, the author believes, has differentiated Canadian satellite design, although she does not speculate on the source of these values. Especially since the late 1960s, Canadian space scientists have specialized in research which addresses specific Canadian needs first and is only secondarily designed to serve foreign markets, through technology developed to serve indigenous needs. Factors of size, distance, and climate have prompted the development of Canada's particular expertise in resource surveys, communications, and meteorological prediction.

A more successful treatment of modern scientific culture may be found in M. Christine King's *E.W.R. Steacie and Science in Canada* (Toronto, University of Toronto Press, 1979). The author, a chemical physicist who also specialized in the history and philosophy of science, was killed tragically in an automobile accident with the manuscript accepted for publication, but the editing not yet begun. King's editor, Dianne Mew, has done a fine job in converting manuscript to book, despite what must have been difficult circumstances. E.W.R. Steacie was a research chemist with the National Research Council of Canada; he joined the NRC in 1936, became director of the chemistry division from 1939 to 1950, and president of the NRC from 1952-1962. His tenure covered the years during which the NRC emerged as Canada's leading scientific institution and a mature institution of international stature.

At the beginning of World War II the NRC had faced formidable challenges. Few Canadian companies were active in industrial research; university research in the sciences was weak; and Canada depended heavily on foreign-born scientists. Within the NRC itself, it was not yet certain what place pure science would occupy; scientists esteemed what they viewed as being "pure science", while government and the public sought practical results. The degree of actual control which the government would exercise over the national laboratories was also unclear, as was the extent to which scientists within the NRC would be left free to follow independent lines of enquiry. Steacie served the NRC through a period of "exuberant expansion" (p. 196), guiding it through the 1950s towards what King argues (in perhaps exaggerated fashion) was the final achievement of "national

scientific autonomy" (p. 59). While institutional development within the scientific and industrial research communities might conceivably have followed widely varying models (a point which the author does not *always* emphasize), Steacie chose a strategic course which mirrored his professional loyalties as a scientist nurtured in high-level university research in "pure" chemistry. Steacie believed that trained personnel were fundamental if Canada was to reduce its dependence on foreign science; accordingly he campaigned to have government inject large amounts of money into universities to stimulate creation of graduate training. Pure science and free enquiry retained free play within the NRC's laboratories. Steacie seems to have been well equipped to champion his policies: an accomplished pragmatist in science and administration, an unquestioning believer in technological progress, and a relentless foe of bureaucratic controls (who chafed miserably at wartime secrecy and the endless demands of committee work).

The book is in many ways a sunny portrait of the NRC, Steacie, and C.J. Mackenzie, Steacie's predecessor — whom King argues was a "conspicuous success" (p. 60) as head of the NRC in part because he believed that administration existed "only so that laboratory divisions could operate at maximum efficiency" (p. 61). The approach is perhaps illustrative of the tendencies of some historians to lionize, rather than analyze Canadian science. Despite the book's strengths, *W.R. Steacie* sometimes veers dangerously close to embracing the "great man" theory of history. In fact, King attributes the NRC's "rapid growth and continued success" during the 1940s and 1950s "to a large degree" to "compatibility of personalities" between the two, evidently talented NRC presidents and their responsible federal ministers, C.D. Howe and Gordon Churchill (p. 164). There is less consideration of what influence post-World War II corporate capitalism and a rapidly expanding mixed economy may have had on the NRC and evolution of "big science".[4] There is also an occasional failure to maintain her distance, more precisely, from Steacie's beliefs and values. Steacie and many of his colleagues embraced a professional ideology which in its purest form incorporated the convictions (here admittedly exaggerated) that scientists attack problems in a uniquely clear-sighted and focused manner, that administrative and bureaucratic controls are, at best, necessary evils, that public accountability is a nuisance, and that applied science is a socially necessary, but comparatively shallow undertaking intellectually and professionally.

Eventually King does set out to assess Steacie's policies critically. King acknowledges that the ebullient confidence of post-war scientists in their

4 Notably, a brief account of the formation of the NRC during World War I underestimates the extent to which non-governmental agencies such as the Canadian Manufacturers' Association and Royal Canadian Institute had earlier promoted establishment of the NRC.

capacity to conquer administrative and financial problems delayed implementation of more serious planning for scientific development. Technology assessments, macroeconomic analyses of science and the economy, and the "management of science" as a field within public policy remained locked in the future (although they have since achieved limited results). King acknowledges also that Steacie's black and white distinctions between pure and applied science were "unrealistic and fallacious" (p. 176). Steacie, she notes as well, categorically denied scientists' responsibility for the consequences of their discoveries: the scientist's only duty was to do good research.[5] Nevertheless, the author's primary loyalties lie plainly with science. The main theme of the book is how science and the NRC won their place in the sun (she believes implicitly that the fates of the two were intertwined). Less attention is paid to the consequences of Steacie's policies for broader Canadian development — and perhaps even for the present state of imbalance in which applied research in the private sector remains dangerously underdeveloped.

Norman Ball's *Heart, Mind, and Vision: Professional Engineering in Canada: 1887-1987* (Ottawa, National Museums of Canada in Cooperation with the Engineering Centennial, 1987) is another, even more flattering account of Canadian achievement. The familiar emphasis on climate and geography is present here as well. *Heart, Mind, and Vision* was written on the occasion of the Canadian Society of Civil Engineers' 100th anniversary. It is an unabashed celebration of engineering accomplishments: "the creation of a modern industrial state on the inhospitable northern half of North America". Ball argues — correctly — that Canadian historians have largely ignored engineering[6] and that the Canadian Pacific Railway (and one might add, other major transportation projects) have eclipsed engineering triumphs in other fields.[7] His book, he hopes, will help earn

5 As an extreme example of his attitudes, as late as 1954 Steacie could discount the possibility "that even a full scale atomic war using Hydrogen bombs would produce sufficient radioactivity to make life impossible over an extensive area" (although simultaneously recognizing that radioactivity carried genetic dangers) (p. 169).

6 A glaring example of the degree to which actual engineering can be ignored is a recent, badly conceived popular history of the Royal Engineers on the west coast between 1858 and 1863. Beth Hill's *Sappers: The Royal Engineers in British Columbia* (Ganges, B.C., Horsdal and Schubert, 1987) says virtually nothing about their actual work and design accomplishments, concentrating on more extraneous details such as travel conditions and the domestic tribulations of sappers' wives. There is no analysis, the sequence of events is often lost in discursive ramblings, and much of the book consists of block quotations from diaries and journals strung together in a vain attempt to create a coherent narrative.

7 Two recent histories of canal construction offer variable rewards to readers interested in the relations between politics, society, and engineering. In his latest in a succession of works on canals in Canada, *Ottawa River Canals and the Defence of British North America* (Toronto, University of Toronto Press, 1988), Robert Leggett asserts that these canals constituted "Canada's

engineering its due recognition. There are some pretensions to depth. Engineers, he notes, have been crucial in shaping not only the built environment, but also the cultural landscape. Ball makes the familiar, intuitively appealing argument that the "structures created by engineering embody the goals, values and ideals of a society" and in turn help mold "the outlook of a people" (p. 7). Yet, as elsewhere, the precise connections can be difficult to draw; the epistemology can soon turn slippery. Ball succeeds only marginally in demonstrating how engineering reflected indigenous values and in turn shaped popular culture — beyond making Canadians more "modern" and "industrial".

As well, Ball's eagerness to praise Canadian engineering often excludes more thoughtful analysis. In particular, Ball's treatment of 20th century Canadian engineering becomes a prosaic compilation of feats of high technology — hydro-electricity, petroleum projects, and odd bits of Canadian trivia, such as our world standing in submersible craft and buses for the handicapped. There is a familiar emphasis on Canadian firsts, as well as her seconds and thirds, as the first country outside the United States to have a working nuclear reactor and the third nation into space (with the Alouette). Ball believes that Toronto's CN Tower, like the Eiffel Tower earlier, has become a symbol of our age (p. 148). It appears mostly to have become a symbol for Toronto.

As a popular survey, however, *Heart, Mind, and Vision* offers some strengths. Some of the technical delineation is very good, as in Ball's description of the massive, ingenious shield and hydraulic ram used to drive excavation forward through rock underneath the St. Clair river during construction of the St. Clair

first major public work" and that the "full story" of the canals "has never yet been told" (p. 3). This is straightforward narrative history, much of it familiar. The book, while an adequate account of the canals, unfortunately provides both too little and too much. The detail surrounding construction of individual locks and sections is often overwhelming — unlikely to be of any interest to readers not innately fascinated with the localities. James T. Angus' *A Respectable Ditch: A History of the Trent-Severn Waterway, 1833-1920* (Kingston and Montreal, McGill-Queen's University Press, 1988) also suffers from a preponderance of detail. This is not a book about "transportation or engineering", Angus contends, but rather about "politics — the politics of dreamers", the dialectics of patronage, party politics, and competing local interests that shaped the canal's glacially slow construction, and the struggle of the canal's promoters to pursue a "vision" (p. 4) which most contemporaries could not see. It is questionable to claim, as Angus does, that — despite the canal's limited practical value and the parish pump politics that guided its progress — "the end was always noble" (p. 68). The canal finally lurched towards completion in 1920 only because the federal Minister of Railways and Canals could not bear to see even a bad job left unfinished. Nevertheless, Angus tells us a lot more than he allows about the political factors surrounding engineering decisions, and the practical tenets and approach of engineers, contractors, surveyors, and canal commissioners. There is also more here on the physical character of construction than appear in most histories of transportation; the result is a richer and more true account.

tunnel. There is fascination to be found even in the most thoroughly unlikely topics, such as the cautious acceptance of concrete as a building material by early 20th century engineers. Yet, other material suggests the currently underdeveloped state of research in the history of engineering. There is a general neglect of Maritime activities. His assertion that "large-scale mechanized mining" (p. 70) first appeared in Canada in Ontario and British Columbia in the 1920s ignores the use of sophisticated technologies such as wire rope haulage, self-dumping skips, and compressed air drills since the 1880s in Nova Scotia mines — many of them technically refined operations.

One theme that does stand out is Ball's attempt to identify a particularly "Canadian" approach to engineering enterprise (although this is not entirely convincing). Ball notes that the original Welland Canal was built as a purely commercial venture; wood used as a building material led to rapid structural disintegration and the locks were built too small to accommodate large vessels. Ball argues that unhappy experiences with the canal resulted in a landmark report in 1837 by the consulting engineer Hamilton Killaly. This led (although by an undescribed process) to "the emergence of a particularly Canadian tradition of engineering", a "system using mixed engineering talent" with government financing and technical expertise employed, as required, in partnership with engineers from the private sector (p. 13). According to Ball, the one primary factor explaining Canadian engineering excellence has been the creation of "mechanisms [designed] to combine the resources and strengths of both" (p. 167). Yet it is difficult to demonstrate that this is a uniquely Canadian emphasis: other countries, the United States included, have strong traditions of mixed private and public ventures. The proposition also begs the question of what might have been achieved if public policy had instead earlier encouraged greater excellence and expansion in private sector industrial research. Some might argue that the partnership reflects weakness rather than strength.

This may be carping. More interesting is Ball's argument that a peculiarly Canadian mode of *construction* emerged during completion of the Rideau canal. The argument is illustrative of the attempts a few historians have been making to find distinctive stylistic traits in Canadian engineering design. When completed, the Jones Falls dam on the Rideau system was the tallest dam in the western hemisphere, "built to last" using permanent, high cost masonry construction in the tradition of European engineering suited to "densely-populated and long-settled areas close to existing centres of trade, manufacturing and skills" (p. 4). Masonry was again used at the Hog's Back near Ottawa, but stone and stone masons were in short supply, and spring floods — at heights never before seen by British engineers — made quick work of the construction. Axemen and timber were readily available; the engineers turned to rubble-filled timber cribs, then to earth-filled cribs. Canadian engineers, Ball asserts, were becoming "attuned" to a young developing nation's need "for quick, functional construction at reasonable costs" (p. 5) and for adaptability, expediency, and innovative exploitation of

previously untapped natural resources. A "Canadian" engineering was emerging. Nineteenth century Canadian railways used temporary work — into which more permanent structures could be later incorporated — to reduce initial costs and produce faster revenues through earlier completion. The construction of the Canadian Northern marked the appearance of a new "philosophy of permanence based on faith in the country's future" — with use of heavy rails, costlier rock fill, and fewer temporary trestles (pp. 49-50). Ball's arguments for an intrinsically "Canadian" style of construction are appealing. However, they do not consider the degree to which contemporary American engineering may have shared the same bias towards present-oriented design and inventive use of native materials.

Richard Jarrell's *The Cold Light of Dawn: A History of Canadian Astronomy* (Toronto, University of Toronto Press, 1988) marks yet another attempt to define the development of a national character — this time within astronomy. This could not have been an easy write. Jarrell faced major problems of documentation, since — for the 20th century in particular — archival materials are often either entirely unobtainable or only partially open to research. Moreover, astronomy's complex development no doubt made the discovery of unifying themes difficult. Those which Jarrell has identified are unfortunately only partially interesting. Canadian astronomy in New France and during the first 80 years of British rule was science practiced by non-Canadians acting in their own interests — generally home governments exploiting astronomy to assist "exploration or exploitation" serving imperial purposes or, in the case of the Jesuits, as "an intellectual pastime or subject of education" (p. 9). After 1840 and the beginnings of responsible government, astronomy became increasingly a science practiced by Canadians to meet Canadian requirements. The Canadian Meteorological Service, formed after Confederation to improve time-keeping for towns and railways and improve weather prediction, was followed by the Astronomical Branch of the Department of the Interior, created to facilitate surveys of the Canadian West. Astronomy became a "practical", "Canadian" science — although Jarrell argues that "most scientific activity occurred in central Canada" (p. 29). The emphasis on practicality had several origins. In the United States, Jarrell argues, private philanthropy and the existence of large universities resulted in astronomy centred on university campuses. In Canada, government dominated astronomy. Canada lacked concentrated populations of a sufficient 'critical mass' to support major educational institutions and the rapid industrialization from which American philanthropists and philanthropic support emerged. In a small developing country, practical science was more valuable than science pursued for science's sake.

After 1905 astronomy turned to more purely intellectual ends. The construction of the Dominion Observatory near Ottawa represented a new commitment by government to science, undertaken largely, Jarrell "believes", because in the flush years of national growth under Laurier, the Dominion Observatory served

as a symbol of "national maturity": a national institution to which government could point, similar to those in major international capitals (Jarrell provides no documentation to support his theory). More than ever, Canadian astronomy became "a distinctive and unique entity both socially and scientifically" (p. 87) with the creation of a basic institutional infrastructure over the next 50 years, including advanced university teaching, new government institutions and research programs, new publications, and formalized contacts with international bodies. Jarrell contends that Canadian astronomy became "professionalised" between 1905 and 1940.

Regrettably, summary may make the book seem more interesting than it actually is. It is a useful book, to be sure; Jarrell has unearthed masses of information on astronomers and their work. Yet the book centres too heavily on people, institutions, and events. There is too little analysis of the *science* itself, little attempt to translate it for the laymen, and only limited indication of its cultural content. The book refers repeatedly to acquisitions of astronomical instruments by their size and type, but with no explanation of their nature and significance. There are also occasional errors in emphasis. Jarrell is surprised that Kingston should have had an observatory in the 1850s before Montreal, "the metropolis of Canada" (p. 45). Kingston was, of course, already a major centre in its own right. An assertion that in 1840 "Canada was a collection of colonies with small populations, few financial resources, and little economic development, virtual *wards* of the politicians at Westminster" (p. 55, my emphasis) overstates Canadian political impotence.

In Susan Sheets-Pyenson's *Cathedrals of Science: The Development of Colonial Natural History Museums During the Late Nineteenth Century* (Kingston and Montreal, McGill-Queen's University Press, 1988) the growth of indigenous institutions is also a guiding theme. *Cathedrals of Science* describes museums of natural history in Canada, Australia, and South America in an attempt to establish patterns of development. Sheets-Pyenson argues that the "advances and expansion" of museums in colonial countries have been less "widely appreciated" that those of major European and American centres (p. 10). Her main foil is a survey conducted in 1893 by F.A. Bather, a curator from the British Museum, who contended that colonial museums were largely dependent on metropolitan museums for their support and concentrated their activities exclusively on local specimens and practical applications. Sheets-Pyenson acknowledges that colonial museums were reliant on metropolises "not only for materials, but also for architectural designs, organizational models, and qualified personnel", yet argues that Bather underestimated colonial achievements — the degree to "which fine institutions were almost literally carved out of the wilderness" (p. 11) and to which colonial museums acquired collections that reflected flora, fauna, and minerals world-wide. Their aims were not merely utilitarian, but also to "educate and morally uplift the middle and lower classes" (p. 12). Only when "big science" demanding huge government subsidies, complex technical equip-

ment, and close teamwork among practitioners emerged in the 20th century did colonial museums lose their standing. Understaffing, combined with the continued domination of museums by individual directors, precipitated their decline. Montreal's Redpath Museum, proud custodian of some 80,000 specimens and once one of the six leading museums in North America, degenerated into little more than "an overcrowded warehouse" (p. 98).

Unfortunately, the book suffers to a degree from a confusion of purpose. Sheets-Pyenson's introduction suggests that she intends moving beyond analysis of museums as institutions to consider the broader implications of their work for science. A number of theories of metropolitan-hinterland relationship are considered: perhaps, for example, "colonial practitioners" acted as "collectors of facts" while "metropolitan scientists" served as "theorists or gatekeepers of scientific knowledge" (p. 15). But comparatively little is said subsequently about how colonial museums actually served or influenced scientific activities. A chapter on "collections" centres primarily on the logistics of collecting specimens through networks of professional collectors and contacts with colleagues in foreign museums. The material is suggestive (as is much of the information presented throughout) but here and elsewhere the author falls short of articulating more significant findings about colonial science, allowing merely in her conclusion that colonial museums encouraged "the first steps toward scientific independence". She suggests that they did so by providing "a haven for natural resources and products of the locality" (p. 101) and by providing eventual training and employment for local scientific workers. It is questionable, however, whether Canadian museums were actually more important initially in developing science than universities or government-sponsored scientific services such as the Geological Survey of Canada.

*Cathedrals of Science* works best as a history of museological development — in fact suggests considerable potential. Yet, chapters on "Leaders and Followers" and "Founding and Funding" often descend into minutiae of detail with hazy associations with larger themes. Preoccupations with anecdote abound. Sheets-Pyenson contends that refusal by the Royal Society of London in 1870 to publish a lecture by William Dawson on Devonian plants "reveals the narrow path that colonial scientists were expected to follow and demonstrates the sanctions that could be applied to them if they strayed". The one incident is slim evidence of censorship. The author contends also that a negative appraisal of the paper by Sir Joseph Hooker delivered a "murderous stroke" (p. 34) to Dawson's scientific career. While Dawson's well-known opposition to Darwinism may have eventually removed him from the mainstream of scientific opinion, his "scientific career" was scarcely at an end in 1870. It is equally questionable to argue that Dawson played "an important role" (p. 30) in the "recently created" Geological Survey of Canada; in the early 1840s when the Survey was established, Dawson was still a young man back in Nova Scotia doing Maritime geology.

Often, much of the more interesting writing on history of science and technology

has come from historians trained initially in Canadian history. Historians more intimately conversant in Canadian historiography have brought a crucial understanding of *context* to their work. For apparent reasons, an internalist approach to science and technology has not proven to be popular. Canadian science and technology has not exhibited the same degree of self-contained development which was evident (although by no means absolute) in 19th century Britain, as one example. While individual Canadians have made numerous contributions to international science, Canadian science and engineering have been largely borrowed, then modified to meet Canadian conditions. The mechanisms of adaptation *can* present a fertile subject of research; analysis of such processes provide an excellent route into understanding the internal dynamics of scientific and technical innovation. Adaptation itself is a creative process; here an internalist approach makes sense, as evidenced, for example, by a recent well researched and lucidly written account of engineering on the Sault Ste. Marie Ship Canal, which provides fascinating insights into the character of technological reasoning.[8] Yet — with such exceptions — Canadian science and technology are themselves often less intrinsically interesting as objects of study than their social origins, and social and cultural impact. Science and technology ordinarily have had their greatest significance in their relationships with broader streams of historical development, and here sensitivity to Canadian historiography becomes critical.

In fact, a number of young historians have discovered that a detailed dissection of technological processes is not only useful, but unavoidable in evaluating larger historical processes. Two labour historians, Craig Heron and Ian Radforth, have addressed technological change dexterously in confronting a fundamental question in Canadian labour history: did the modern mass production and machine techniques of Canada's Second Industrial Revolution "de-skill" Canadian workmen? Both historians dispute the existence of a simple pattern.

8 Robert W. Passfield's *Technology in Transition: The 'Soo' Ship Canal, 1889-1985* (Ottawa, Environment Canada, Canadian Parks Service, 1989) is a superbly researched and lucidly written account of engineering in the Sault Ste. Marie ship canal. The Sault canal pioneered internationally in its use of concrete and clay-puddle walls, electrically powered lock machinery, and an emergency swing dam bridge designed to protect the canal and locks in the event of the gates being breached. For a while the canal's one lock was the largest in the world. There is some consideration of external factors. Passfield cites political and economic influences in decisions to open the canal and to build it on massive scale (access through the American canal at the Sault was vulnerable to American caprice and the Macdonald government harboured ambitions for an enormous traffic in grain from the Canadian West). Economic imperatives for rapid movement of grain at the beginning and the end of the shipping season dictated the use of electrically driven gates: the oil used in cold weather in hydraulic mechanisms became sluggish. But generally Passfield takes an strictly internalist approach, which here seems entirely appropriate.

Heron's *Working in Steel: The Early Years in Canada, 1883-1935* (Toronto, McClelland and Stewart, 1988) analyzes the conversion of Canadian steel mills from plants heavily dependent on manual labour and simple, 'disconnected' machinery to modern automated factories in which materials followed "an integrated flow-through" (p. 48). This is fascinating material. Heron argues that despite elimination of traditional skills, heavily dependent on craft secrets, new skills emerged. Modern industrial technology did not mean that the "the old dichotomy of craftsmen and labourers" gave way to "a mass of mindless machine-tending jobs", but instead produced "a new hierarchy of jobs with less gap between the least and most skilled and with considerable demands for responsibility and judgment from workers filling them" (p. 71). Apart from the new competence which the new technology encouraged — perhaps even an "intellectualization" of the skills (p. 54) required in handling intricate machinery — Canadian plants retained major "pockets of technical backwardness" (p. 49) in which little technological de-skilling could occur. Although Canadian steel plants turned increasingly to time clocks, cost accounting, and bureaucratic managerial frameworks in the early 20th century, "systematic" management was unable to reach into the various production departments to control shop floor operations. White collar managers could never entirely master the abstruse workplace knowledge which the traditional shop floor superintendents and foremen commanded. Time-honoured patterns of decentralized management by frontline supervisors persisted. As a result, when labour conflict emerged within steel mills, company exercise of raw authoritarianisms had more influence in emasculating militancy than either "the theories of Taylorism or technological organizations of Fordism" (p. 172). Throughout, Heron describes steel mill processes with vigour and lucidity and with a fine eye for describing the fundamental nature of technological systems.

Radforth shows the same sensitivity for the character of technology in his excellent history of *Bushworkers and Bosses: Logging in Northern Ontario, 1900-1980* (Toronto, University of Toronto Press, 1987). Like Heron, Radforth concludes that technology had a different and less determinant impact than is commonly believed, although remaining significant. Radforth is fully alive to the complexities of technological processes. He believes that the survival alongside science-based pulp and paper making, of "time-honoured" techniques in lumbering "that depended heavily on learning-by-doing, the strength of men and horses, and natural factors, such as the friction reducing qualities of snow" provides excellent examples of what historians have termed "combined and uneven development". Historians' traditional belief that technology followed "distinct stages of development" make little sense (p. 25).

Technological change reflected an elaborate play of factors. Although chainsaws introduced in the period 1949 to 1952 did not yet increase profitability, they won a strong following among cutters because of the diminished physical effort which the chainsaws required. The breakthrough in chainsaw design occurred

through the combined efforts of the Woodlands Section of the Canadian Pulp and Paper Association, forest companies, chainsaw manufacturers, and woods labourers themselves. Development of more fully manoueverable articulated vehicles in the 1950s was made possible only by new developments in hydraulic systems. While most equipment manufacturers were American-owned, the design and manufacture of harvesting equipment took place largely in Canadian branch plants.

A final innovation, wheeled skidders, greatly facilitated year-round work; management insisted on team coordination in mechanized work, reducing the autonomy of the bushworker, now forced to keep pace with the skidder. Yet what happened, Radforth argues, was "not so much a straightforward trend toward deskilling, but a complex process of job redesign that involved trade-offs in terms of autonomy, technical skill, and status, and a considerable amount of reskilling" (p. 219). Skidders required new proficiencies to repair complex mechanisms and to manoeuvrer heavy machines across difficult terrain. What deskilling took place was not the product of a "hidden agenda" among engineers to control production and workers. Although engineers often embrace cultural values and a "model of man" that produce similar results, engineers are often blind to the latent "political" effects of their decisions. Bushworkers themselves, prompted by the blandishments of salesmen, actually introduced the chainsaw into the bush. There was little potentiality for radicalization. While union vigilance reduced management's freedom of manoeuvrer — forcing management, for example, to accept reduced work weeks — bushworkers welcomed the new technology. They did so, Radforth argues, not only because "they were part of a North American culture that celebrated the triumphs of technology, but also because in the logging industry, mechanization appeared to bring higher wages, lighter, steadier work, and portable new skills" (p. 236).

David Zimmerman also rejects any hint of technological determinism in his recent monograph, *The Great Naval Battle of Ottawa* (Toronto, University of Toronto Press, 1989), a resoundingly negative appraisal of Canadian scientific and technological prowess during the Second World War. Unlike Ball's book, this exhibits little nationalistic self-congratulation. Zimmerman's work follows and in many ways complements recent research which has questioned assumptions of Canadian naval capability during the war.[9] His subject is the failure of Canadian scientists, politicians, and naval authorities to provide Canadian naval escorts in the North Atlantic with adequate advanced anti-submarine technol-

9 See Michael Hadley, *U-Boats Against Canada: German Submarines in Canadian Waters* (Kingston and Montreal, McGill-Queen's University Press, 1985); Marc Milner, *North Atlantic Run* (Toronto, University of Toronto Press, 1985).

ogy — especially, advanced radar. Zimmerman argues that Canada's participation in the Battle of the Atlantic was perhaps "the most vital of all contributions to the Allied effort" (although perhaps a debatable assertion): "the only one where Canadian officers had a large say in strategic planning and control of Allied forces and where Canadian science and industry made an irreplaceable contribution" (p. 4). Yet Royal Canadian Navy escorts "went to sea with inferior, outdated, or unusable equipment". While the National Research Council became the prime wartime agency for military research, it did not share the naval command's priorities; Canadian scientists achieved a "minimal influence on military planning" (p. 5). "It was not that Canada lacked technical expertise", Zimmerman contends, "but that there was a dearth of talent that could link operations, staff, and the scientist" (p. 84). Zimmerman's argument skilfully exploits the complexity of political and organizational relationships that could — and here did — influence the development, and failure, of Canadian technology.

For example, the King government's insistence on naval autonomy left Canada largely to fend for itself without British help. C.J. Mackenzie, appointed head of the NRC in late 1939, lacked vision and administrative savvy; his primary aim throughout the war was to increase the power and prestige of the NRC — a goal frequently in conflict with the requirements of the war effort. Absurdities reigned, with the King government discriminating against Maritime ports by awarding ship-building and repair contracts to Great Lakes and St. Lawrence River facilities, whose harbours were ice-bound in the winter. C.D. Howe "followed his own personal blueprint for the post-war economy", Zimmerman writes, in which Ontario and Quebec — crucial to electoral majorities — were to become the economic "fulcrum" for Canada. This was unconscionable, Zimmerman believes: "the Allies could have lost because of the failure to create adequate repair and refit facilities close to the crucial fighting in the Atlantic" (p. 91). A successful program to produce asdic sets was accompanied by failure to underwrite radar research, although far more essential. Low British regard for Canadian scientific potential helped deprive Canada of British discoveries in radar. For years, scientific communication with the United States had been easier than that across the Atlantic. This had been expressed in Canadian memberships in American professional societies and reliance on "North American" (p. 70) scientific journals; the NRC did not establish a London field office until 1941. "NRC scientists were forced to reinvent radar, using civilian tubes and circuitry" (p. 33).

Throughout 1941 the long-wave Surface Warning One Radar (SWIC) monopolized research, inhibiting work on the considerably more precise short-wave radar. Other schemes would also preoccupy the NRC, the most important being the RX/C radar. Only one submarine sighting would ever be positively attributed to SWIC. Little effective interchange occurred between men in the ships and the laboratory. Naval Service Headquarters actively discouraged field innovation, and the naval offices and technicians assigned to the NRC lacked "battlefield (sic) experience" (p. 55). The Navy, in turn, neglected high technology and was

noticeably deficient in technical staff. Failure to install a hybrid American-Canadian radar antenna available early in 1942 contributed materially to disastrous losses in RCN convoys in the fall of 1942. Only late in 1942 did the RCN finally establish a program for short-wave radar.

Everywhere the RCN fell behind the Royal Navy in introduction of anti-submarine detection and attack technology. Neither the Canadian naval minister, Angus L. Macdonald, nor the Chief of Naval Staff, Percy Nelles, saw the need to provide naval staff with scientific advisors. Production of RX/C radar and the RX/U antenna lagged, largely because of the NRC's failure to produce prototypes applicable to mass production and the navy's failure to provide experts to advise in manufacture. Eventual failure of the RX/C finally destroyed "the delicate fabric of NRC-RCN relations, and the RCN's involvement in Canadian radar production" (p. 123). Canadians turned to American radar.

Scientists had not become an integral part of naval planning; the NRC and Mackenzie had in turn remained content with the situation so long as NRC control of research and development was not threatened. Far-sighted proposals to establish an independent science directorate to oversee naval research foundered on Mackenzie's refusals to help the navy become self-sufficient in science. In June 1944, Commander G.A. Worth, officer in charge of the RX/C project, withdrew the navy from the NRC radar program — ironically in view of the fact that by the end of 1944 the NRC's new 268 radar, in development since 1942, was now in full production and was being rapidly adopted by the British Navy. Here the British admiralty finally provided the crucial scientific liaison that would ensure that the new radar worked well in operational conditions.

Even as lengthy a summation as this does scant justice to the complexity of Zimmerman's argument. This is a superbly researched, closely reasoned monograph. The book's failings are comparatively minimal. We learn relatively little about the internal dynamics of research within the NRC and, more precisely, the factors driving scientists towards preoccupations with certain programs; a more detailed analysis of why limited contact with field conditions actually hampered success *might* also have helped. It is also unfortunate Zimmerman has not related his findings to larger historiographical issues more systematically; his analysis underlines few implications in particular for history of Canadian science, although there are many there. Finally, Zimmerman is silent on any wartime research conducted for the other services which might possibly have offset his bleak portrait of the NRC. This is otherwise a fine piece of work.

A critical spirit extends as well to J. Rodney Millard's *The Master Spirit of the Age: Canadian Engineers and the Politics of Professionalism, 1887-1922* (Toronto, University of Toronto Press, 1988). This is not history of engineering *per se*, but rather a social history of engineers and of engineers' efforts to pursue professional status — although not the aims of disinterested service often associated (perhaps naively) with other professions such as medicine. His subject is primarily *civil*

engineers in the modern sense of term.[10] Because of the book's primary institutional focus on the Canadian Society of Civil Engineers and the Engineering Institute of Canada, there is a comparatively lean emphasis on mining, mechanical, chemical, and electrical engineers.

No matter. The book is graced by a balanced, sometimes brilliant appreciation of engineers' political and social values. Engineers were no social theorists, Millard believes; they drew heavily on British and American ideas, and were often "superficial and unsystematic" (p. 12) in their thinking. Engineers nevertheless expressed identifiable attitudes. Engineers viewed themselves as "the foremost members of an elite community of right-thinking progressives accustomed", according to one commentator, "to dealing with fact and with immutable natural laws" (pp. 15-6). Neither politicians, thought prone to corruption, nor elective government impressed engineers; many engineers instead championed government by experts on a corporate model. Engineers had natural claims to social leadership — being skilled in both applied science and the arts of organizing large numbers of employees into "effective human machines". Labour and capital were mutually dependent elements in a "complex machine" that required only the engineer's deft design to achieve harmony and efficiency (p. 16). Yet, while cloaking themselves in assertions of expertise, public service, and professional integrity, engineers did not develop a coherent set of explicitly *professional* values. "The main thrust of engineers' thought", Millard argues, "was technocratic, not professional" (p. 22). Engineers in fact "masquerade[d] in professional clothing in order to achieve political objectives" (p. 24).

These objectives reflected social and economic anxieties. At the formation of the Canadian Society of Civil Engineers in 1887 engineering schools provided engineers' only tangible mark of increased "professional" status. Engineers lacked popular recognition; engineers were often "overshadowed by the grandeur" of the massive engineering projects they designed and "stigmatized by negative nineteenth century British aristocratic attitudes to manual labour". No legal strictures protected entrance into the engineering profession. "Anyone could practice" (p. 9) and, prior to World War One, employers often hired the least expensive personnel. Many engineers lacked the independence of the self-employed professional. Salaried engineers, forced to subsist on fixed earnings, saw their real incomes eroded by inflation. Municipal engineers, especially, faced conflicting demands of professional judgement and employee loyalty, complicated by political factionalism within municipal governments. Initial attempts in the late 1880s to establish professional licensing failed in the face of opposition from

10 Nineteenth century mining engineers and mechanical engineers were also commonly considered to be "civil engineers", distinguishing them from military engineers.

what disaffected engineers termed the "Montreal clique" (p. 38), a loose body of comfortably established, conservatively-minded engineers centred around McGill University, who effectively controlled the CSCE. The Montreal clique ensured that the CSCE became "the institutional expression" of its "pre-industrial professional values", combining "the advantages of a learned society and of a gentleman's club" (p. 39). Conservatives opposed legal protections instituted, they felt, in defence of class privileges and mediocrity. Conservative engineers instead sought to nurture professionalism through ongoing professional learning by which engineers would acquire the "esoteric, technical knowledge" (p. 10) essential to their employers. This was a central Canadian club. Most Maritime civil engineers did not join the CSCE.

By the end of the First World War, wartime inflation and fierce competition within a now overcrowded profession at last convinced the engineering leadership to commit themselves seriously to regulatory legislation. Engineers wielded claims that the monopoly won through licensing would protect the public interest by excluding incompetents. In reality, Millard argues, professionalization was merely "a pragmatic political device" (p. 11) aimed at the protection of engineers' economic and social interests; the licensing associations established by engineers in the 1920s "were the middle-class counterparts to trade unions, business associations, and combinations" (p. 10).

While *The Master Spirit of the Age* is a competent and generally convincing piece of analysis, there are shortcomings. Millard tells us only little about what engineers actually *did*: what actual functions they performed within municipalities and companies and why the technological choices they made occasionally raised ethical issues. The title is also a bit unfortunate; it is not at all clear that engineers ever became the "Master Spirit of the Age", for all their importance in proclaiming "the secular gospel of social engineering" (p. 11). While simultaneously emphasizing throughout the book that most engineers possessed limited powers and limited public esteem, Millard suggests that engineers may "perhaps" have become "more influential in shaping the values of the developing industrial state than were many contemporary social reformers, such as Social Gospellers" (p. 11); he offers little substantiation. Nor has Millard demonstrated that, even after the achievement of professional licensing in the 1920s, engineers "had emerged as the pre-eminent middle-class experts" (p. 146). Fortunately, this is not the main brunt of the book's argument.

A more concerted integration of technological and social themes may be found in the essays collected in Norman R. Ball (Senior Editor), *Building Canada: A History of Public Works* (Toronto, University of Toronto Press, 1988). *Building Canada* is a composite history of Canadian public works consisting of 13 essays on such subjects as bridges, canals, and irrigation commissioned from historians conversant with the research. These highlight the disparate means by which geography, culture, and social demands led to implementation of new public works technologies. As history of technology, the book takes few

major new historiographical initiatives; much of it is textbook material, and rather general. Nor have most essays been based heavily on original research. Yet this is no ultimate sin. In fact, one strength of *Building Canada* is the amount of information it contains drawn together from disparate sources which do not themselves concentrate sufficiently on technical themes to be interesting as history of technology.

Readers will find a variety of intriguing insights within various individual essays. Doug Baldwin combines an analysis of engineering, medicine, urban politics, and professionalization to create an excellent account of Canadian public sanitation. Baldwin describes how the miasmic theory of disease, which preached that illness originated in the vapours given off by foul waters, encouraged construction of sanitary sewers in the 19th century, ironically sometime before a growing understanding of water-born disease become a greater stimulus to sanitation projects. Letty Anderson, on the other hand, observes that fears of fire and of escalating insurance premiums initially had much more influence on the establishment of urban water supply systems than did public health, which only later became a major factor. Christopher Andrae makes an admirable beginning towards correcting a persistent neglect of the hard details of operation and construction technologies by railway historians; railways were, of course, massive achievements in civil engineering and organizational logistics as well as "national dreams" and creatures of freight rates. Tight editorial control is evident throughout *Building Canada*, although there is some unavoidable overlapping, and two separate essays contain conflicting figures regarding the extent of initial GO commuter train trackage (see pp. 80 and 109). Ball's authors have not been hesitant to pass critical judgement. Floods have been common in Canada, notes A.A. Den Otter, but government has generally been slow to institute watershed control until disaster strikes.

Difficulties in thematic direction are more evident in Barbara R. Robertson's *Sawpower: Making Lumber in the Sawmills of Nova Scotia* (Halifax, Nimbus Publishing Limited and the Nova Scotia Museum, 1986). Robertson's book is, however, a step beyond most treatments of Canadian milling, which have tended to treat milling as a romantic pioneer craft and ignored its concrete technological components.[11] The brief text accompanying a recent collection of photographs, *Watermills of Ontario, Quebec and Maritime Canada*, by W. Stephen Cooper (McGraw-Ryerson Limited, Toronto, 1988) is fairly typical. The book makes summary attempts to describe milling as an industrial technology, but the photographs sacrifice documentary values in favour of aesthetics. Picturesque

11 An exception is Carol Priamo's *Mills of Canada* (Toronto, McGraw-Hill Ryerson, 1976), which is nonetheless flawed by brevity and unclear description.

shots of mill exteriors prevail. In Robertson's hands, however, sawmills become more than the quaint staple of pioneer museums; they become elaborate industrial constructions, increasingly complex as the 19th century progresses. The stuff of change becomes the gritty mechanics of such items as hydraulic turbines, removable saw teeth, and steam engine governors — as well as the technological enterprise of dozens of Nova Scotian mill owners and machinists, whose individual personal fortunes are detailed in the text. Photos, engravings, and drawings illustrate the material culture of mill layouts, mill carriages, steam boilers, valve systems, drive mechanisms, and other of the complex technical elements of sawmilling.

This is more than simply a history of sawmilling. The book also provides much information about Nova Scotia industry and industrial engineering as a whole, ironically because Robertson often wanders off topic. Robertson has plumbed a remarkable variety of technical sources, including engineering journals and trade catalogues, normally neglected by historians. Unfortunately, at the same time, the book often loses its way in the detail, much of which undoubtedly reflects the fragmentary information found in newspaper notices, almanacs, and directories on which Robertson also relies. The book also falls short in a tendency to unsophisticated judgment and a failure to pull the diverse data together successfully to create a coherent analysis of sawmilling as a whole. A concluding chapter attempts a decadal periodization of the industry's development and the emergence of new institutional mechanisms for technological diffusion. Robertson seems too naively sure of the effectiveness of these institutions. Despite what the author suggests, the Halifax Mechanics' Institute was notoriously ineffective in training local mechanics in the technical disciplines; working class Haligonians stayed away in droves. Robertson theorizes that the Nova Scotia Industrial Exhibition of 1854 "must have done much to stimulate manufacturing in Nova Scotia" (p. 152). Yet it is unlikely that the motley exhibits of low technology manufactures had any such effect. The Technological Institute founded in Halifax in 1878 may have briefly marked "a new phase in technical education", yet was a resounding failure that lasted a scant two years and can hardly be considered a prominent "feature" of the 1870s (p. 152). *Sawpower* is a brave attempt to write a comprehensive history of sawmilling; it is unfortunate that the book was not subjected to a sterner editorial critique.

The pleasures to be found in Robert Bothwell's *Nucleus: The History of Atomic Energy of Canada Limited* (Toronto, University of Toronto, 1988) lie in analyses of character and circumstance rather than in concerted analysis of technological development. This is corporate biography rather than history of engineering. *Nucleus* nonetheless often places technological choices under close scrutiny. In 1942, Bothwell writes, the "coincidence of war" brought "nuclear research both urgency and finance" and resulted in an organized immigration of engineers and scientists across the Atlantic to begin work on nuclear research p. 444). Although the initial purpose was not clear, the result was a joint Anglo-

Canadian atomic laboratory in Montreal, which barely survived the maladroit personality of its first director, Hans von Halban, and initial American refusal to share research and assistance. Nevertheless, Halban's successor, John Cockcroft, converted plans for what had initially been intended to be "a prototype for a bomb factory" (p. 444) into the construction of a facility which planned the first working nuclear reactor outside the United States at the NRC's famous nuclear research centre at Chalk River: a reflection of the surprisingly low relative cost of atomic research, government's belief that status as an "atomic power" could bring Canada international prestige, and C.D. Howe's benign views of science as a 'good thing' for the economy. American interest in atomic power created similar interest in post-war Canada.

Technological choices, Bothwell infers, had as much to do with leadership and politics as they did with technological imperatives. The appointment of W.B. Lewis as director at Chalk River in 1946 brought a crucial energy and intelligence to the facility's administration. When the issue became finding a mechanism to market and develop nuclear power ("normal government procedures" were inappropriate for an industrial enterprise) C.J. Mackenzie initially suggested that Chalk River be divided into two entities, with scientific work continuing under the aegis of the NRC and the engineering assigned to a new crown corporation. Howe disagreed: "conflict between R&D and operations was inevitable, no matter what form was adopted" (p. 144). In April 1952 Atomic Energy of Canada Limited was officially established, and with it a relationship between consumer, manufacturer, and scientist which was unusually close for a nuclear industry. Howe sought to ensure that close cooperation existed between the AECL (the scientific designer); Canadian General Electric (the prime manufacturer); and their major customers, the provincial utilities (among whom Ontario Hydro would soon dominate). The AECL's elimination of CGE from the "triumvirate" (p. xv) in 1958 left the AECL in an even more intimate relationship with Ontario Hydro, now its primary user. Here, as in other fields, Canada triumphed through specialization. Canada was unique in concentrating predominately on one specific type of reactor, which used heavy water to control chain reactions and natural uranium as fuel. From this emerged the Canadian CANDU reactor.

This is a fine piece of research and rigorously sympathetic account of leading personalities and decision-making processes. Throughout, the book provides painstakingly clear analyses of nuclear technology. (Bothwell is no nuclear scientist; he has evidently received an excellent tutoring.) If there is any criticism to be made, it is that Bothwell's immersion in the values of corporate managers and scientists may have occasionally restricted the book's analytical perspective. Perhaps future research will tell us more about the broader emergence of a new post-war scientific establishment in Canada, and do so perhaps by employing a more "anthropological" analysis of the scientist and his culture. In the meantime Bothwell has made a fine contribution to the history of one aspect of "big

science" in post-war Canada.

Biography can be a dangerous pursuit, with the author too submerged in the fate of his subject to tackle larger themes. The botanist John Macoun, however, turns out to have been almost a natural subject for biographical treatment. From his appointment as botanist for the Geological Survey of Canada in 1881 to his retirement in 1912, Macoun (along with his son, James, and devoted assistant, William Spreadborough) essentially comprised the natural history division of the Geological Survey. W.A. Waiser's excellent *The Field Naturalist: John Macoun, the Geological Survey, and Natural Science* (Toronto, University of Toronto Press, 1989) tells us much about Macoun, Canadian inventory science in the 19th century, and the political uses of science. This is a consciously critical and fair-minded account of Macoun, based on impressive research, which conveys a rich sense of scientific life in Canada in the 19th century.

Macoun was the quintessential *collector*, responsible for amassing astonishing numbers of specimens for the GSC, who believed his primary role was to discover new species and their geographic spread. Macoun believed that Darwinism, the study of the life history, anatomy and physiology of organisms, and the analysis of function over form which followed from Darwin's ideas, were irrelevant. Increasingly the science Macoun preformed became anachronistic. His role was to discover *abundance*. In five different expeditions between 1872 and 1881 Macoun was sent to investigate the agricultural potential of the Canadian North-West. Macoun was ambition incarnate. The explorations offered a magnificent opportunity to become recognized "as one of the few men who understood the real potential of the Canadian North-West" (p. 35). Where the earlier explorers Henry Youle Hind and John Palliser "had seen a forlorn empty wilderness", Waiser writes, Macoun "evoked images of 'a land with untold wealth in its soil' where life means an unending pleasure" (p. 16). Macoun was no charlatan: he believed implicitly in what he had discovered, supremely confident of his scientific skills. There was a theoretical basis for some of his conclusions, which disputed equally fallacious theories that the southern prairie grasslands were the northern extension of the "Great American Desert" presumed to fill much of the trans-Mississippi American west; and the decade during which Macoun explored the west was a particularly wet period for the prairies. But the consequences were disastrous, lending scientific support to an optimistic view of the west which resulted in federal homestead policies which deprived settlers of crucial assistance at the pioneering stage. Canadian politicians saw science not as a search for knowledge but rather as an instrument to promote economic growth and national prestige. Macoun and other like-minded scientists espoused what Trevor Levere has termed "an entrepreneurial scientific ideology" (p. 55). Macoun's findings served the Conservatives well. His eventual reward, in 1881, was a long-coveted appointment to the Geological Survey.

The repercussions were considerable. Macoun opposed the directions in which natural science was moving, following Darwin. With the blessing of the

government, the Geological Survey remained wedded to inventory and description, imbedded in the Victorian age. But because Macoun lacked the time or expertise to classify the numerous specimens he so avidly collected during his annual field trips, classification increasingly fell to American specialists to whom Macoun sent his finds. These specialists, not surprisingly, soon learned to exploit the situation and were soon telling Macoun "not only how to collect but what and where" (p. 83). John Macoun, James Macoun, and William Spreadborough, Waiser relates, became "little more than 'hewers of wood and drawers of water'" (p. 206). Moreover, the Macouns' seeming success in acquiring specimens through their annual "sweeps" of a region conveyed the unfortunate impression that the Macouns, acting alone, could themselves "assemble a representative collection of Canada's biological life" (p. 205). They couldn't. Their collecting methods were far from scientific and, in fact, somewhat haphazard. The result, combined with Macoun's anachronistic rejection of laboratory study, was that the Natural History Division never grew to become a proper vehicle for biological research. Macoun's acquisitions — many of which remained untreated and uncatalogued — gradually accumulated to create what Macoun and allies in engineering and scientific circles saw as a "national collection". Pressures of space to house and display "these so-called national treasures" (p. 207) led eventually to construction of the Victoria Memorial Museum, which became the National Museum of Canada.

Perhaps for lack of sources, Waiser does not detail in depth the mechanisms by which Macoun — a self-taught botanist and former farmer — initially gained scientific recognition. Yet this is small criticism. *The Field Naturalist* provides a wonderfully concise account of the work of the GSC in natural history and a balanced, frequently insightful treatment of the politics of practical science in 19th century Canada.

Many of the strengths which history of science has to offer are illustrated amply as well by Suzanne Zeller, *Inventing Canada: Early Victorian Science and the Idea of a Transcontinental Nation* (Toronto, University of Toronto Press, 1987). Zeller examines the growth of a scientific culture and establishment in pre-Confederation Canada to show how Victorian inventory science in various disparate ways helped "invent" the idea of a trans-continental nation — helping create a sense of common identity based on scientific understanding of the Canadian physical environment and a climate of opinion in which westward expansion and confederation of the provinces would seem "natural" conclusions from the influences and character of the material environment. Science was a mechanism for re-shaping perceptions of the physical character of British North America, the North-west, and their potential for Canadians. Thus, growing geological realization that the united Canadas held no coal helped shift attention eastward to the coal beds of the Maritimes. This and the fact that the physical boundaries of geological horizons themselves appeared to expand beyond artificial political boundaries lent credibility to the idea of a wider union.

Agricultural necessities demanded the development of botanical inventory. The resulting scientific study of the geographical distribution of plants turned eyes northward in the search of new data and there re-cast notions of the limits of arable land. It also led Canadians to perceive uniqueness and identity in the existence of distinctive, northern plant forms persisting straight across the continent. Terrestrial magnetism and meteorology, like botany, helped Canadians "re-evaluate their position and even their character as a northern people" (p. 116) and re-set perceptions of the north-west as a land fit for cultivation.

*Inventing Canada* presents a subtle argument, which convincingly exploits 19th century science's role as a powerful motor for re-shaping fundamental perceptions. Beyond its utilitarian function, Victorian inventory science also carried deeper social, political, and cultural undertones. Science "lent a sense of purpose and meaning" to the laborious challenge of settling the provinces (p. 5). Scientific theories as to the roots of natural variation suggested that where hardy northern plant species had emerged, so would "hardy and virtuous variations of the Canadian people" (p. 264). Socially conservative champions of meteorology and geomagnetism saw "practical" science as a powerful "cultural adhesive" (p. 134), uniting classes, cultures, ideologies, languages, and provinces in a common article of faith.

This is in many respects a pioneering study. Along the way, Zeller provides a wealth of detail on the personality of scientists, science, and scientific culture and a not bad general introduction to mid-19th century Canadian science. Much of this has not been explored before. Her main cast of characters, with exceptions, consists of English British North Americans in the two Canadas. It is less clear what messages the majority of Maritimers and French Canadians received from the inventory sciences, but to have demanded more than has been already delivered seems excessive. This is ground-breaking research, which admirably transmits the mentality of the period and convincingly recreates important aspects of intellectual life in Victorian Canada.

Zeller's book illustrates much of what is exciting about history of science and technology: as one example, its capacity to enter into long forgotten conceptualizations of environment and nature in a manner rarely possible in conventional social and political history. It yet remains to be seen how well history of Canadian science and of Canadian technology will stand up as distinct, independent fields; at this point both seem most meaningful approached more strictly as parts of the larger historical equation. Whatever the case, although new articles are now constantly appearing within the mainstream historical journals, as well as an increased flow from the university presses, the surface has been barely scratched. To cite just one example, much more is to be learned about the relations between science and secularization in Canada — and even the degree to which science actually promoted secularization (outside intellectual circles). Perhaps also the borders of history of technology should be stretched and historians should look more rigorously at those "techniques" of administrative management in govern-

ment and the private sector which have profoundly influenced the modern Canadian polity. The various mechanisms by which the Canadian population has been inculcated in technological and scientific ideas are as well as yet just partially understood, as is the degree to which 19th and 20th century Canadian culture has been dominated by an ideology of practicality. There is much to be done, and it should be very rewarding.

DON MACLEOD

## Some Participants Missing But A Great Deal Present

VOLUME VII OF THE *Dictionary of Canadian Biography* (Toronto, University of Toronto Press, 1988) examines the lives of prominent British North Americans, or individuals who had a significant impact upon British North America, whose year of death falls in or between 1836 and 1850. In certain cases careers peaked sometime before dates of death, or dates of death occurred sometime after the time period covered, and so this volume actually offers much more and much less than events occurring and individuals active in the 1830s and 1840s. From a national perspective, the North and West of what would eventually be the Canadian nation are more in evidence than in Volumes I to VI while Upper and Lower Canada clearly have taken centre stage. Nonetheless Atlantic Canadian history continues to be reasonably well served by the *D.C.B.* If the entries dealing with this part of Canada are isolated for special consideration they do provide revealing insights concerning political, economic and social development, or non-development. Indeed, reading together the New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland contributions allows some interesting comparisons.

As can be expected, an examination of prominent and significant individuals within developing colonial societies will not do justice to the inarticulate whether in an ethnic, class or gender sense. In addition, despite a commendable attempt to include artists, writers, educators, and an appreciation of cultural development in general, at this time the focus within the colonies was largely on other more basic matters. To be sure, an excellent taste of the "intellectual awakening" within Nova Scotia is provided in the biographies of John Young (pp. 930-5) and Thomas McCulloch (pp. 529-41). The plight of the artistically inclined is revealed in William Valentine's activities. While described as the "most important portrait painter in early 19th-century Nova Scotia" he apparently reverted to house painting when business was slack (pp. 875-6). The difficulties of those on the margins of society are exemplified by the Indians and those interested in their