Symposium contribution / Contribution à un symposium

Culture collections in Canada: perspectives and problems[1]

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Abstract: Culture collections are custodians of microbial resources of vital importance to science and society. These facilities are essential in enabling contemporary and future research in basic and applied sciences, and in integrating more than 75 years of records on Canadian microbial diversity. Culture collections often carry on because of dedicated efforts of key individuals. However, they become vulnerable to loss or dismantling when individuals retire or shift research direction in response to program reorganization or loss of funding. The need for conservation of, and long-term access to, microbial resources has long been recognized, and since 1962, six workshops have been held to address concerns about their future. In 1988, a report by the Task Force on the Status of Culture Collections in Canada made several recommendations. Key among these were that (1) specialized collections of strategic importance be supported, (2) an advisory committee be established to include members from different sectors of the scientific community, (3) government agencies allow user fees to be charged for access to collections, which would then be used for operational support, (4) the Natural Sciences and Engineering Research Council of Canada expand the infrastructure program to fund culture collections, and (5) technologies for improved access to vital data on strain history and properties be developed. Follow-up meetings resulted in a recommendation that an expert committee on plant and microbial genetic resources be established under the Canadian Agricultural Research Council. Although these activities resulted in increased recognition and support for some collections, in general, the situation of Canadian collections is no better, and is probably more dire, than in 1988. A national strategy is urgently needed to ensure the long-term care of valuable microbial genetic material.

Key words: culture collections, microbial genetic resource centres, biodiversity, systematics.

Résumé : Les collections de cultures sont des dépositaires de ressources microbiologiques d'importance vitale pour la science et la société. Ces installations sont essentielles parce qu'elles permettent de faire des recherches en sciences pures et appliquées et le permettront encore dans l'avenir, et qu'elles intègrent plus de 75 ans d'information sur la diversité microbienne au Canada. Les collections de cultures se maintiennent souvent grâce au dévouement de personnes clés. Cependant, elles deviennent sujettes à être perdues ou démantelées lorsque les personnes en place prennent leur retraite ou que leur recherche est réorientée pour répondre à des impératifs de réorganisation de programme ou pour cause de fin de financement. Le besoin de conserver et d'avoir accès à long terme à des ressources microbiennes a depuis longtemps été reconnu et, depuis 1962, six ateliers eurent lieu pour traiter des questions concernant leur avenir. En 1988, un rapport du Groupe de travail sur les collections de cultures au Canada a fait plusieurs recommandations. Parmi celles-ci, les plus importantes étaient (1) que les collections spécialisées d'importance stratégique devaient être soutenues, (2) qu'un comité consultatif constitué de membres provenant de différents secteurs de la communauté scientifique soit mis en place, (3) que les agences gouvernementales permettent que des frais soient exigés pour l'accès aux collections, lesquels pourraient ensuite être utilisés pour soutenir les opérations, (4) que le Conseil de recherche en sciences naturelles et en génie du Canada étende son programme d'infrastructures au financement des collections de cultures et (5) que des technologies pour améliorer l'accès aux données vitales sur les antécédents et les caractéristiques des souches soient développées. Des réunions de suivi débouchèrent sur la recommandation de mise en place d'un comité de spécialistes des ressources génétiques végétales et microbiennes sous la responsabilité du Conseil de recherches agroalimentaires du Canada. Quoique ces actions aient augmenté la reconnaissance et le soutien de quelques collections, la situation globale des collections canadiennes n'est pas meilleure et résulte probablement davantage en paroles qu'en action, comparativement à 1988. Il est urgent de se

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doter d'une stratégie nationale pour garantir à long terme la garde du précieux matériel génétique microbien.

Mots clés : collections de cultures, centres de ressources génétiques microbiennes, biodiversité, taxonomie.

Introduction

Culture collections, or microbial-gene banks, are centres where organisms of scientific or industrial interest are maintained in a living form. In addition to conserving organisms, collections acquire and provide access to a wealth of information on microorganisms and their properties. Although it is recognized that collections are essential for scientific research and training, there are concerns that resources are insufficient to support existing Canadian collections and that many are being eroded or lost entirely. While collecting, describing, and classifying organisms was formerly considered a fundamental research endeavor, the general decline in systematic expertise within universities and government (Canadian Museum of Nature 1995) has been concomitant with a decline in support for collections. Since 1962, several workshops, including stakeholders from government, universities, and industry have been held to address these concerns and to develop a plan to assure the continued maintenance of these vital resources. In 1988, a Task Force on the Status of Culture Collections in Canada, established under the Ministry of State for Science and Technology, made several recommendations (Sanderson and Russell 1988), but there has been no agency or network to enact them. In 2001, the Canadian Agricultural Research Council, Ottawa, Ont., issued a memorandum expressing concern about the number of collections for which maintenance had been terminated and stating that action needed to be taken to ensure continued maintenance and possible increase in culture collection capability in Canada. This is illustrated in part by data from the directories of Canadian collections published in 1986 (Weldon et al. 1986) and 1994 (Agriculture and Agri-Food Canada 1994) that showed a reduction in the number of collections from 140 to 86 in the interval between publications. While vulnerable Canadian collections may be identified, it is difficult to mount an effective campaign to save them because of lack of an official agency to oversee collections and of financial support to affect a rescue. Existing collections have limited ability to take in orphaned collections, yet the latter often contain isolates that have been at the core of various scientific programs and (or) unique records on indigenous species. Saving these resources and making the data publicly accessible would add to the knowledge base on species distribution and improve, for example, our ability to monitor plant pathogens. The purpose of this article is to review the roles and types of microbial collections, to consider issues affecting Canadian collections, and to present some recommendations that will help to ensure their future. The section concerning funding focuses on university-based collections because other presentations at the workshop dealt with government and industry collections. To provide up-to-date data, I requested information from several curators, but the interpretation of the responses is entirely my own.

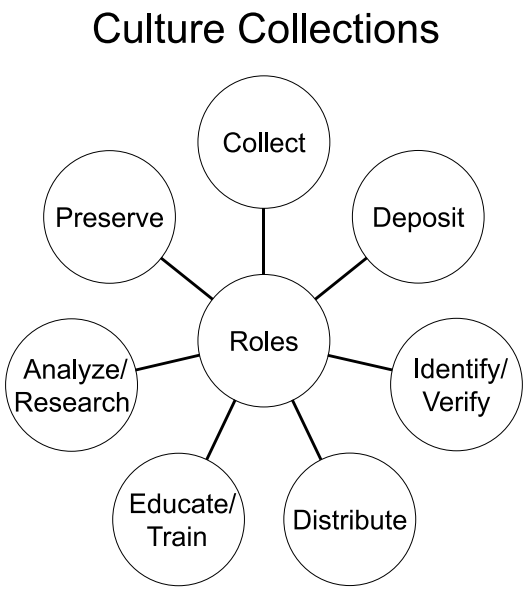
Why retain microorganisms?

Culture collections are responsible for stewardship of microbial resources of vital importance to science and society. Basic and applied research depends upon the availability of suitable biological material. Microorganisms are tools on which various processes are based and are one of the most important sources of natural products. Systematic study depends upon having access to type material as well as to reference material representing the genetic diversity of a species. The microorganisms currently maintained in collections represent only a fraction of the world's resources, and for fungi alone, it has been estimated that collections hold approximately only 1% of the more than 1 000 000 species that are thought to exist (Hawksworth 1991). Organisms held in Canadian collections are the result of intense cataloguing and characterizing of the Canadian microbiota over vast regions of the country for approximately 75 years. The historical records associated with these deposits provide valuable information on biodiversity and species range, and these data can help to evaluate emergence of new or introduced species, especially plant pathogens. Unfortunately, much of this information is currently inaccessible because it has not been transferred to publicly accessible databases. As collections are lost, this legacy of information will also be gone. As a consequence, future research funds will have to be directed to rediscover, reisolate, and recharacterize microorganisms that were already known.

Roles and types of culture collections

The roles of culture collections are to acquire, conserve, and distribute microorganisms and information about them to foster research and education (Fig. 1). Collections serve as repositories for valuable isolates of historical, geographical, taxonomic, agricultural, medical, veterinary, or industrial significance. It is important to deposit isolates described in publications to ensure future access and allow for scientific reproducibility. For example, most journals today require the deposit of sequences in public repositories, and it should also be mandatory to deposit the cultures from which the sequences are derived. Sequences are sometimes incorrect and it is impossible to determine this without access to the original culture (Bridge et al. 2003; Sigler et al. 2002). Journals should require a culture deposit in a publicly available culture collection and, ideally, in more than one collection in different countries to assure later access. Of course, this requires that there be appropriate collections, and this could tax collection resources if a lot of strains are involved. Equally important is the need for deposition of cultures described in processes such as the production of a specific compound. In many instances, the process cannot be reproduced without access to the specific isolate

Fig. 1. Roles and services of culture collections.



either because the isolate was misidentified or it was incompletely characterized, i.e., not identified to species.

It is important that organisms held in collections be properly identified and genetically stable. The identity of an isolate should be verified at the time of deposit and whenever preserved material is restocked. Techniques for preservation are similar for most microorganisms, with freezing in ultra low temperatures and freeze-drying being the methods of choice. However, some microorganisms are fastidious in terms of requirements for optimum preservation. Nonsporulating fungi, for example, do not survive freeze-drying. It can be challenging and labor intensive to preserve fastidious organisms such as algae and many types of fungi, particularly ectomycorrhizal fungi. Degenerate (or contaminated) cultures have little value to most researchers, so it is important to maintain high standards of quality control, which can only be done with skilled and well-trained personnel.

Strain data are often as valuable as the organism itself, and researchers need to have access to this information. Well-developed databases are crucial to this knowledge transfer. Researchers can select the strain(s) most appropriate for a particular research application through print catalogues or online databases; however, it should be noted that communication with the curator is often important in ensuring that the most appropriate strain is selected. In the age of bioinformatics, these data will become even more valuable.

Culture distribution and exchange are fundamental roles of culture collections. Ideally, cultures distributed should be well characterized, properly identified, and genetically stable. Collections often hold isolates that are less well characterized, which may be of value for biodiversity studies and screening for metabolites or other properties. Such isolates may not be listed in publicly accessible databases. Researchers want access to the cultures as quickly as possible and at the lowest possible cost, yet fees for cultures and transport are increasing. The process for international shipping has become complicated, time consuming, and an impediment to culture exchange. Problems arise from lack of harmonization of biosafety, transport, and quarantine regulations (see also section Culture exchange).

Collections are centres of research and training. A high-quality collection is associated with an active research program. Research is fundamental in developing significant collections, in characterizing strains on deposit, which adds to their value, and in attracting, to the collection, users who require cultures or expertise. The name of the organism is the key to accessing information about it. Not only is it important that individual isolates be correctly identified, but also collections must keep up-to-date with taxonomic and nomenclatural changes and be involved in the development of new methods for characterization. Collections' staff foster knowledge of microorganisms through academic and professional training. Short courses or workshops are provided in-house or in association with scientific societies to train personnel from medical, environmental, industry, or government laboratories who have responsibilities for isolating and identifying microorganisms, diagnosing disease, quality control, fermentation, collection management, etc.

Types of collections

Collections develop in different ways depending upon their initial purpose and the staff associated with them. Centralized multigroup collections comprise a strong representation of all or most groups of microorganisms and provide all services, including an International Depository Authority for patent strains. There are no Canadian collections of this type, but the National Microbiology Laboratory, Health Canada, Winnipeg, Man., has been established as an International Depository Authority. Centralized multigroup collections occur in the U.S.A., Germany, and Japan. The American Type Culture Collection, Manassas, Va., has a curatorial staff of ca. 80 and holds more than 70 000 strains (including cell lines). The German Collection of Microorganisms and Cell Cultures, Braunschweig, Germany, has a curatorial staff of ca. 26 and maintains more than 17 000 strains. Canadian collections are specialized to include representatives of a single genus (e.g., the *Salmonella* Genetic Stock Centre, University of Calgary, Calgary, Alta.) or of a single group of organisms or functional group (e.g., fungi, wood-decay fungi, yeasts, algae, *Ureaplasma*, etc.).

Status of Canadian collections

Two directories of Canadian collections were compiled to determine the types of services offered and the types and numbers of organisms and where they were held. The first, published in 1986 and based on a broad survey (Weldon et al. 1986), listed 140 collections, of which 23 were recognized as of strategic importance based on their unique scientific characteristics, national or international, use, and (or) size of the collection. Priorities to secure these collections were identified as: (1) better technical and financial support (70%) and (2) the development of online catalogues (61%) and an online directory of culture collections (60%). The second directory, in 1994, listed only 86 collections (Agriculture and Agri-Food Canada 1994). While unique and scientifically valuable material is held in many smaller individual research collections, the collections identified as strategic in 1986 are the ones encompassing the roles and

Table 1. Canadian collections listed by World Data Centre for Microorganisms (WDCM).

WDCM No.	Name of collection	Acronym	Institution
6	Félix d'Hérelle Reference Centre for Bacterial Viruses	HER	Université Laval, Sainte-Foy, Que.
38	Forintek Culture Collection of Wood-inhabiting Fungi	FTK	Forintek Canada Corp., Sainte-Foy, Que.
50	Forest Pathology Culture Collection, Pacific Forest Research Centre	DFF	Canadian Forest Service, Victoria, B.C.
73	University of Alberta Microfungus Collection and Herbarium	UAMH	University of Alberta, Edmonton, Alta.
91	Department of Biology / M.A. Lachance	UWOPS	University of Western Ontario, London, Ont.
150	Canadian Collection of Fungal Cultures / National Mycological Herbarium (DAOM)	CCFC	Agriculture and Agri-Food Canada, Ottawa, Ont.
237	Fredericton Stock Culture Collection	FSC	Canadian Forest Service, Fredericton, N.B.
250	Department of Medical Biology, Université Laval	MUL	Cité universitaire, Sainte-Foy, Que.
338	*Salmonella* Genetic Stock Centre	SGSC	University of Calgary, Calgary, Alta.
535	North East Pacific Culture Collection	NEPCC	University of British Columbia, Vancouver, B.C.
605	University of Toronto Culture Collection of Algae and Cyanobacteria	UTCC	University of Toronto, Toronto, Ont.
634	Lallemand Yeast Culture Collection	LYCC	Lallemand Yeast Inc., Montréal, Que.
740	Plant Gene Resources of Canada	PGR	Agriculture Canada Research Branch, Saskatoon, Sask.
741	Collection de génomes d'organismes symbiotiques	CRBF	Université Laval, Sainte-Foy, Que.
742	Labatt Culture Collection	LCC	Labatt Brewing Co., Ltd., London, Ont.
744	The Fungus Culture Collection, Northern Forestry Centre	NoF	Canadian Forest Service, Edmonton, Alta.
745	Janet A. Robertson Collection	UUC	University of Alberta, Edmonton, Alta.

Note: Data are from Web site http://wdcm.nig.ac.jp/hpcc [updated 31 July 2003].

services as outlined in Fig. 1, including depository, distribution, identification, consulting, and training.

Collections providing such services are members of the World Federation for Culture Collections (WFCC; http://www.wfcc.nig.ac.jp/index.html), and of national networks where they exist. The WFCC–MIRCEN World Data Centre for Microorganisms, Shizuoka, Japan, registers collections and maintains data on their holdings (World Federation for Culture Collections 2003). Currently, 464 collections from 62 countries are registered. Of these, 17 are listed from Canada (Table 1), a decline from the 23 collections recognized as strategic in the 1986 directory. Details on the current status of four government, eight university, and one industry collections are provided in Table 2. As can be judged from these data, virtually all collections listed are vulnerable at the retirement, death, or loss of position of the curator. It is very difficult to develop a succession plan, especially within universities, since positions are not tied to collections.

Orphaned collections

Collections are vulnerable to being orphaned, i.e., abandoned by the institution when there is a loss of the key position associated with the collection or a change in research direction or priorities. It is easy to identify vulnerable collections but hard to mount an effective campaign to save them. No Canadian agency or group has a mandate to hold institutions accountable to ensure the future trusteeship of collections, nor is there any means of acquiring central financial support to rescue or assist in transfer of orphaned collections. In some instances, material is discarded before the scientific community is aware of the problem. The resources of existing collections are already stretched, and taking in orphaned collections taxes those resources even further. Table 3 provides examples of some fungal collections that have been acquired by either the Canadian Collection of Fungal Cultures (Agriculture and Agri-Food Canada, Ottawa, Ont.) or the University of Alberta Microfungus Collection and Herbarium (University of Alberta, Edmonton, Alta.) over the past 10 years. Orphaned collections often include invaluable scientific material. Dr. R. Danielson's material of ectomycorrhizal fungi was compiled over many years of research in the boreal and montane regions of Alberta. Cultures established from fruiting bodies collected from specific sites are of value in reestablishing forests in areas now in urgent need of major reclamation, such as the northern tar sands. In Canada, one of the experts on ophiostomatoid and other wood staining fungi is Dr. J. Reid from the University of Manitoba, Winnipeg, Man. During his research career, he described a number of new species and established a significant personal culture collection and herbarium. Because of inadequate funding for maintenance of this collection, Dr. Reid was constrained in his abilities to maintain and distribute these materials. Most of his reference collection is not available anywhere else in the world and thus represents unique and prized material of value to Canadian and world scientists.

Issues affecting collections

Current needs of collections are the same as those identified in the 1986 directory (Weldon et al. 1986) and in the

Table 2. Status of some Canadian collections.

Acronym[a]	Agency type	Holdings[b]	Staff[c]	Comments
CCFC	Government	12 000 F	2	Acquiring threatened collections but staff resources are limited
FSC	Government	225 F	1	Downsized; V@R
NoF	Government	2 800 F	0 or 1	Not recently curated so holdings are probably lower; new staff member will take on responsibility in part as time permits
DFF	Government	500 F	1	Downsized; V@R
FTK	Industry	2 300 F	1	Supported by industry; funding insufficient
CRBF	University			Transferred to CCFC
HER	University	500 BPH	1[d]	Funded from individual research grants and user fees; funding insufficient
NEPCC	University	340 A	1 or ?	Downsized; lack of funds
SGSC	University	10 000 B	2[d]	Partial funding from NSERC MFA; curator has retired from an academic position but continues to maintain the collection; working on succession plan; a mirror collection will be transferred to U.S.A. if grant is obtained from National Science Foundation
UAMH	University	10 200 F	2.5[d]	Partial funding from NSERC MFA; acquiring threatened collections but staff resources are limited; V@R
UTCC	University	500 A	0.8	Partial funding from NSERC MFA; operates with benefit of Advisory Committee of several faculty from five Canadian universities; acquiring threatened collections but staff resources are limited; V@R
UWOPS	University	5 000 Y	1[d]	Funded from individual research grants; V@R
UUC	University	2 000 M	1[d]	Curator retired; collection may transfer to U.S.A. or France but resources insufficient for transfer

Note: Data based mainly on responses to a survey conducted by the author. NSERC MFA, Natural Sciences and Engineering Research Council of Canada, Major Facilities Access grant; V@R, vulnerable at retirement or resignation of curator.

[a]Acronyms for culture collections are defined in Table 1.

[b]A, algae and cyanobacteria; B, bacteria; BPH, bacteriophage; F, fungi; M, mollicutes; Y yeast.

[c]Differences in staffing levels relative to holdings reflect the complexities of maintaining organisms of different types and (or) available financial resources.

[d]One full-time-equivalent Curator paid by university has other academic duties.

Table 3. Examples of fungal collections orphaned or vulnerable over 10 years.

Collection	Agency type	Transferred to	Reason
PRL	Government	CCFC	Retired or research priorities shifted
Waterloo	University	CCFC	Retired
J.W. Paden	University	CCFC	Died
E.G. Setliff	University	CCFC	Retired
D.W. Malloch	University	CCFC	Retired (3000)[a]
Edible (S. Davies)	Government	UAMH	Research priorities
J. Reid	University	UAMH	Retired
R.M. Danielson	University	UAMH	Retired
J.P. Tewari	University		Retired (1800)[a]

Note: CCFC, Canadian Collection of Fungal Cultures, Agriculture and Agri-Food Canada, Ottawa, Ont.; PRL, Prairie Regional Laboratory, Saskatoon, Sask.; UAMH, University of Alberta Microfungus Collection and Herbarium, Edmonton, Alta.

[a]Approximate number of cultures in collection at time of retirement in June 2003.

report by the Task Force (Sanderson and Russell 1988) as being important to secure the future of Canadian collections. These include: (1) adequate staffing, (2) adequate space and equipment, (3) information management and knowledge transfer through development of databases and directories, (4) means to expedite culture exchange through harmonization of quarantine and transport regulations, and most importantly, (5) stability of funding.

Staffing

The staff complement of some Canadian fungal collections is very low compared with that of international collections (Table 4). Culture and preservation of micoorganisms are often complex, labor-intensive tasks. Isolates may require weeks to months and an array of culture media to obtain optimum growth, and species or isolates may demonstrate differences in survival after preservation. All collections face the problem of stockpiled materials, but living material must be dealt with in a timely manner or it will be lost. In contrast, the urgency is not as acute for nonliving specimens in herbaria and natural history collections. All microbial collections have staffing levels identified as inadequate. They need well-trained, permanent technical staff. There is a perception, especially by grant review committees, that

Table 4. Staffing levels at selected fungal collections.

Collection	Country	Holdings (approximate)	Staff (approximate)	Ratio staff:holdings
CBS	Netherlands	45 000	20[a]	1:2200
IMI	U.K.	26 000	10[a]	1:2600
NRRL	U.S.A.	44 000	19	1:2300
CCFC	Canada	12 000	2[a]	1:6000
UAMH	Canada	10 000	2.5	1:4000
UWOPS	Canada	5 000	1	1:5000

Note: CBS, Centraalbureau voor Schimmelcultures, Utrecht, Netherlands; CCFC, Canadian Collection of Fungal Cultures, Agriculture and Agri-Food Canada, Ottawa, Ont.; IMI, International Mycological Institute, Egham, U.K.; NRRL, Agricultural Research Service (ARS) Culture Collection, U.S. Department of Agriculture, National Centre for Agricultural Utilization Research, Peoria, Ill.; UAMH, University of Alberta Microfungus Collection and Herbarium, Edmonton, Alta.; UWOPS, M.A. Lachance, Department of Biology, University of Western Ontario, London, Ont.

[a]Directly involved in curation; excluding taxonomic scientists.

short-term assistance in the form of students or casual labor will suffice, but it takes a great deal of on-the-job training to develop the skills and knowledge required. Although the job may seem simple, it is complex and requires individuals with the right aptitude. Untrained or poorly trained individuals are often an impediment to short-staffed collections because if left unsupervised, they may introduce contamination or replacement errors that may not be discovered until it is too late to avoid permanent loss. Such errors undermine the credibility of the collection as scientists are reluctant to acquire misidentified material. As noted above, professional staff, especially systematists, are crucial to the long-term future and viability of collections. They are required to secure funding, provide advisory or consulting services, keep accessions taxonomically up-to-date, and ensure continued development of the collection through acquisition of new material.

Space and equipment

Collections occupy large amounts of space and continue to grow. Most collections lack sufficient space and equipment for expansion. Space shortages are acute, especially at most universities. Taking in orphaned collections adds to stresses on existing collection space and storage capacity. Equipment is needed for basic work, including cryofreezers, autoclaves, storage refrigerators, microscopes, computers, etc., and to add value to accessions, including equipment for DNA sequencing and image analysis. Many collections were established between 1945 and 1970, and equipment such as microscopes often date from this period! It is often difficult to obtain funding for basic operational and expensive equipment such as autoclaves and walk-in refrigerators, and university central support for these basic microbiology facilities is declining.

Information management

Both collections' staff and users want rapid and efficient access to information on microbial resources. From the collection management perspective, databases should allow for easy entry and updating of information, efficient searching and reporting protocols to find data and to produce required documents such as catalogues, information on preserved stocks, shipping forms, etc. The time and skill level required to enter and update data is often vastly underestimated. Collections' staff are challenged to keep information up-to-date. Major Canadian collection have searchable internet databases that are easily accessible by users worldwide. Web-based catalogues are often a subset of data from the main database and it is important to develop methods for seamless transfer of data. From the user's perspective, a disadvantage is that Web-based data from different collections are not harmonized, and it may be difficult for users to synthesize the data from different sources.

Database development and upgrading and computer equipment acquisition are linked to appropriate levels of funding for collection operation. Although the 1988 Task Force report recommended that the Ministry of State for Science and Technology commit funds to strategic collections for hardware and development costs for databases, the Ministry was later realigned and no central agency support was realized. Approximately $100 000 per year, over 5 years, to strategic collections was suggested as a reasonable commitment to fund this work. Curators need assistance from information technology (IT) specialists in developing and enhancing the database and in choosing and maintaining equipment. In large organizations, however, curators may have less input into the design and development of the database as IT personnel may work more independently; an end result is that the database may serve users' needs better than collections' needs. Universities have moved away from centralized computing, leaving collections' staff with no or limited IT support, thus requiring the hiring of specialist consultants. Databases are not static and need to be redefined on a regular basis to incorporate new types of data (e.g., digital images, sequence data) and to better serve collections' needs. Additional challenges and financial pressures come from the rapidity of changes in computer hardware and software, threats to data security and integrity from hackers and viruses, and need to upgrade skills to keep abreast with all the changes.

Culture exchange

The deposit and distribution of microorganisms are fundamental roles of culture collections. Culture exchange is impacted by regulations governing the safe handling, containment, classification of agents according to risk, packaging and shipping of biological materials and infectious agents, and prohibitions governing agents deemed as possi-

ble biological weapons. Although it is recognized that some regulations are necessary for safe handling and transport of microorganisms to help prevent exposure in the workplace and in transit, what is problematic is the lack of harmonization of regulations and differing levels of stringency. As regulations become more stringent, often with little influence from the scientific community, they place increasing financial and administrative burdens upon both culture collections and the scientists that use them (see section by Sigler and Flis in Padhye et al. 1998). Priorities for collections at both the international and national levels are to (1) develop consensus in risk (hazard) classification of organisms, (2) change regulations governing transport of Risk level 2 organisms, and (3) provide a more streamlined system for permits. We need to develop a means by which strategic Canadian collections' staff can work with Canadian Food Inspection Agency and Health Canada's Office of Laboratory Security to obtain standing permits for importation of most organisms.

Transport of cultures is governed by agencies such as the International Air Transport Association (IATA) and by domestic regulations that vary among countries (Rohde and Claus 1995). A requirement for use of standardized packaging (Brown and Simione 1994; Rohde and Claus 1995) has been a major improvement to ensure safe shipping of biological material. However, the shipping of cultures has become complicated, time consuming, and costly. The shipper is responsible for safe transport according to risk level. Microorganisms are assigned to risk groups according to their pathogenic potential (De Hoog 1996; Kennedy 1996). While definitions of risk groups are generally agreed, there is no international consensus on the assignment of species within the groups. Noninfectious perishable biological substances, i.e., organisms from Risk Group 1, are not regulated. Infectious Substances (IATA UN2814) or Etiologic Agents (U.S.A.) placed in Risk Group 2 or Risk Group 3 are regulated and must be sent as dangerous goods (class 6.2). Transport of dangerous goods requires personnel trained to ship and to receive, engenders a large amount of paperwork and higher costs, and in the case of most organisms from Risk Group 2, fosters fear of biological hazards that may be more perceived than real. In aftermath of 11 September 2001, additional potential barriers to transport include the possibility of living cultures being irradiated, or a requirement to ship by cargo-only aircraft. Many destinations are not served by cargo-only planes, and such shipments are then sent by truck or halted altogether.

The postal, quarantine, and safety committee of the WFCC is monitoring regulatory changes worldwide (Smith 1996). The reclassification of organisms as Risk Group 2 is an issue of particular concern. There is a tendency for organisms to be assigned to higher risk levels, often with little supporting evidence and without input from the scientific community. An example of this occurred in Canada in 2001 when Health Canada posted, on their Web site, a very long list of microorganisms raised from Risk Group 1 to Risk Group 2 and requiring containment Level 2. As well, a large number of organisms were deemed to be zoonotic agents, thus ultimately requiring permits from two agencies for importation of any organism bearing this designation. Canadian scientists responded by pointing out the dubious hazards presented by many of the posted organisms, and the lists of pathogens were removed from the Web site. Lists of organisms can be useful to both regulators and scientists by clearly identifying which organisms are regulated, but hastily constructed lists have adverse consequences for the Canadian scientific community, especially if not harmonized with international ones. Expertise of culture collections' staff could be helpful to regulatory bodies in assisting with risk classification, assessment of pathogens, or biosecurity issues.

One way to expedite the international transport of organisms from Risk Group 2 is to use the same approach as approved for shipping of organisms from Risk Group 2 within Canada. Transport Canada regulations provide an exemption so that cultures of most organisms from group 2, except for seven species, can be sent in compliance with packaging and shipping regulations for Diagnostic Specimens (IATA 650). This approach maintains the stringent safety standard but eliminates the requirement for dangerous-goods paperwork and the high costs associated with shipment of such goods. The WFCC committee is endeavoring to have the Canadian model adopted by the United Nations as it would eliminate current barriers to international shipping of organisms from Risk Group 2.

Funding

Key recommendations of the Task Force (Sanderson and Russell 1988) were that specialized collections of strategic national or international importance be attributed adequate financial support, that the Natural Sciences and Engineering Research Council of Canada (NSERC) Infrastructure Grants, now Major Facilities Access (MFA), be continued and expanded to fund strategic university-based collections, and that collections within government be attributed sufficient resources but with the proviso that some revenue could be obtained from fees for services. An advisory committee representing both collections' staff and users, and modeled after the Expert Committee on Plant Gene Resources, was considered as crucial to develop policies and strategies to ensure the continued maintenance of microbial resources.

Funding for university-based collections

Currently, three university collections receive partial operational funding through NSERC MFA grants (Table 2). The MFA and the prior infrastructure program have been very valuable in providing some stable baseline support. Collections funded through MFA have been encouraged to obtain additional revenues through charging fees for cultures and services. Since the introduction of the program in 1990, the three collections have been evaluated in the same competition. This has been considered beneficial because concurrent review by the grant selection committee provides for enhanced focus on the needs of collections and a means for comparing the scope and complexity of the work involved in maintaining different types of microorganisms. The process changed in 2001 when two collections were given 2-year extensions as part of a process to smooth-out the total number of grant applications per year. It is not yet known whether this separation will adversely affect outcome. The NSERC process is highly competitive, and all

applicants must deal with similar problems, but a collection's existence is threatened at the time of each renewal. Annual budgets are usually exhausted by the time that the results of the competition are announced, leaving specialized trust-funded staff under threat of layoff and the future of the collection in jeopardy if budgets are reduced. Although some grant programs have been extended to 4 years, MFA grants remain at 3 years, and the performance measures for funding renewal are less clear than are the criteria for obtaining support initially. Budgets are tied to income from user fees but income varies annually according to users' needs for cultures or services. Funding levels are generally insufficient to hire or retain professional associates, yet, these individuals are crucial to sustaining the appropriate level of care and to ensuring delivery of high-quality services. Canadian research programs traditionally receive lower levels of support than American ones, but the difference in financial support for two bacterial genetic stock centres is significant. The *Salmonella* Genetic Stock Centre at the University of Calgary currently receives $20 000 per year in NSERC MFA funding, while the *Escherichia coli* Genetic Stock Centre at Yale University, New Haven, Conn., receives over $200 000 per year in National Science Foundation funding.

The NSERC Framework for researchers working with university-based collections (NSERC 2003) recognizes that university-based collections "are essential for scientific and cultural research and for training future generations of researchers", encourages researchers holding large collections to apply under the MFA program, and recognizes that the document's recommendations for good practices have financial implications. Costs related to maintenance of collections are now considered eligible expenses under NSERC grants. Regrettably, this change in policy comes too late for some collections that have been orphaned. However, NSERC's position offers hope that some additional university-based collections will receive funding if sufficient resources are allocated to the MFA program. One thing that is crucial is to develop a mechanism whereby NSERC-funded collections can continue to receive funding during the transition phase of succession. It will be necessary to provide funds over a 2- or 3-year period to allow for the retirement and replacement of the key individual holding the academic position associated with a collection, otherwise there can be no assurance of continuation of the collection during this period.

Priorities

Appointment of an advisory committee with members from different sectors was identified as a priority by the Task Force (Sanderson and Russell 1988) and at follow-up workshops (Baillargeon et al. 1993; Stevenson 1991). The Expert Committee on Plant and Microbial Genetic Resources of the Canadian Agricultural Research Council was established in 1994. In 2001, this committee identified threatened microbial collections as a national issue requiring action. As discussed above, the needs of collections are clear. It is crucial that the Expert Committee work with collections' staff as well as with administrators to bring these to the attention of higher levels of government and to the funding agencies. Additionally the committee, working with the collections' staff, must develop a strategic plan to ensure responsible stewardship of collections and to meet the requirements of the scientific community. If resources are to be secured, it will be crucial to develop succession plans, and institutions must be held accountable for fate of collections. There needs to be a process for intervention when collections are threatened. Collections often are sustained because of dedicated efforts of one or two people, and a loss of one key individual can have devastating consequences. Ultimately, well-funded collections are viewed more favorably by their home institutions. However, some irreplaceable collections will be lost and others will erode if their value is not recognized through ensuring their financial support.

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