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Review

The Fungal Genetics Stock Center in the context of a world wide community of *ex situ* fungal germplasm repositories

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ARTICLE INFO

Article history:
Received 13 May 2011
Accepted 5 July 2011

Keywords:
Culture collection
Genetically modified organisms
World Federation for Culture Collections

ABSTRACT

Most fungal biology researchers depend on culture collections, or more aptly, *ex situ* fungal germplasm repositories, either for the materials upon which they work, or as a long-term home for their materials after their projects are finished. These collections are broadly distributed and typically supported by the local government. The large number of collections, notwithstanding, some collections have greater impact than others. This review will discuss the fungal germplasm repositories around the world with special attention paid to the Fungal Genetics Stock Center. To facilitate their activities collections have joined together in networks, both locally and internationally. Additional information on public policy and how it impacts collections will be presented and the impact of collections will be highlighted.

1. Introduction

Ex situ biological repositories preserve materials away from their natural environment. Because they sequester the materials, they eliminate the impact of most natural and artificial selection. In this regard, they provide a genetic image of the environment at the time of their isolation. Essentially, repositories of genetically characterized or manipulated materials serve as a *de facto* time machine for biological materials. The materials are made available without regard to the passage of time and assure that future researchers can build upon the accomplishments of past researchers. Repositories exist for all manner of biological materials, although some organisms are more amenable to live storage than others. Plants (Li and Pritchard, 2009) and agriculturally important animals (Roosen *et al.*, 2005) are maintained both as living mature specimens in experimental farms and gardens and as preserved living material in *ex situ* repositories. These repositories are different from herbaria and natural history museums in that the materials are living and can be used for future experimental biology as well as for agricultural, industrial, or pharmaceutical development and production. Similarly, repositories of microbial germplasm maintain living material which is used for research and development across every industry (Stern, 2004). These repositories include materials used for taxonomic purposes (Stackebrandt, 2011), industrial production (Bentley and Bennett, 2008), myriad applications in agriculture (Martin and Bull, 2002), and pharmaceutical science (Demain and Adrio, 2008). While there are a growing range of collections which preserve environmental or clinical specimens (Riegman *et al.*, 2008), these collections are not typically focused on preserving living materials, but rather on providing access to material associated with human genetics or healthcare delivery.

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doi:10.1016/j.fbr.2011.07.001

Collections, or to use the term currently in vogue, Biological Resource Centers, provide more than just strains. In addition to the traditional deposit and accession of microbial strains, these centers also provide significant services and materials. Among these are safe deposit, strain identification, preservation, training and consultation. Some collections will provide biological or other materials including genomic DNA, genome or gene libraries, antibiotics, enzymes or antibodies, or specialized glassware for manipulating or storing microorganisms.

While culture collections often have a taxonomically broad mandate, there exist repositories that are dedicated to fungal germplasm (Tables 1 and 2) and such repositories serve every part of the scientific community. Most *ex situ* fungal germplasm repositories hold type specimens or strains used in the chemical or pharmaceutical industry. Others hold materials important for industry and agriculture. The US National Science Foundation supports collections of which emphasize genetics through it's Living Stock Collection program. Along with the Fungal Genetics Stock Center, this program supports collections of genetically characterized strains of *Escherichia coli*, Bacillus, and Chlamydomonas, as well as collections of Drosophila, algae, and other higher eukaryotes. While each of these collections could serve as the focus of a review of their impact on their respective research communities, this is beyond the scope of the current review which focuses on the Fungal Genetics Stock Center as an example of global *ex situ* fungal germplasm repositories.

2. The FGSC

The FGSC was established in 1960 and has survived the retirements of two directors (Raymond Barratt and John A. Kinsey) as well as three moves (McCluskey, 2003). The FGSC collection has grown to over 23,000 accessioned strains as well as tens of thousands of non-accessioned strains (Fig. 1). These latter strains are mostly comprised arrayed sets of Magnaporthe,

Table 1 – *Ex situ* fungal germplasm repositories

Name	Support	Scope
Fungal Genetics Stock Center	US National Science Foundation	Genetic systems
Forest Products Laboratory	US Department of Agriculture	Forest pathogens and symbionts
USDA NRRL	US Department of Agriculture	
Fusarium Research Center	Penn State University	Fusarium
International Culture Collection of VA Mycorrhizal Fungi	US National Science Foundation	VA Mycorrhizae
USDA–ARS collection of entomopathogenic fungal cultures	US Department of Agriculture	Entomopathogenic fungi
Pfaff yeast collection	University of California	Wine and environmental yeast
World Oomycete collection	University of California/USDA	Oomycetes
ATCC fungal collection	NSF/Fees	Type strains, Patent deposit
Centraalbureau voor Schimmelcultures	Royal Netherlands Academy of Arts and Sciences	Taxonomy, Patent deposit
Deutsche Sammlung von Mikroorganismen und Zellkulturen	Federal Ministry of Research and Technology	Type strains, Patent deposit
Mycothèque de l'Universite catholique de Louvain	Belgian Federal Science Policy	Agro-Industrial fungi and yeasts
The University of Alberta Microfungus Collection and Herbarium	Natural Sciences and Engineering Research Council of Canada	Fungal diversity, medical fungi
Colección Española de Cultivos Tipo	University of Valencia	Taxonomy and diversity
Portuguese Yeast Culture Collection	Fundação para a Ciência e a Tecnologia	Yeast
Micoteca da Universidade do Minho	Micoteca da Universidade do Minho	Service
UK National Culture Collection	Biotechnology and Biological Sciences Research Council (UK)	Taxonomy, Service
CABI	Self Supporting non-profit	Taxonomy, Service, Patent
Center for Fungal Genetic Resources (Korea)	Government supported	Magnaporthe mutants
Korea Research Institute of Bioscience and Biotechnology BRC	Government supported	Taxonomy, Service, Patent
Nite BRC	Government supported	Taxonomy, Service, Patent
IMCAS Biological Resource Center	Institute of Microbiology, Chinese Academy of Sciences	Taxonomy, Service, Patent
Agricultural Culture Collection of China	Chinese Academy of Agricultural Sciences	Taxonomy, Service
IBT Culture Collection	Technical University of Denmark	Taxonomy, Service
VTT Culture Collection	Technical Research Centre of Finland	Identification, Service, Patent
Collection des Champignons de l' Institut Pasteu	Centre de Ressources Biologiques de l'Institut Pasteur	Taxonomy, Service
All-Russian Collection of Microorganisms (VKM)	Russian Academy of Sciences	Taxonomy, Service, Identification, Patent

Table 2 – Networks of culture collections

Active	Acronym	Status
World Federation for Culture Collections	WFCC	Active
US Federation for Culture Collections	USFCC	Defunct
UK Federation for Culture Collections	UKFCC	Active
European Culture Collection Organization	ECCO	Active
Global Biological Resource Center Network	GBRCN	Demonstration project
Asian Biological Resource Center Network	ABRCN	Active
International Society for Biological and Environmental Repositories	ISBER	Active

Cryptococcus or Candida gene deletion mutants and are generally distributed as a set. The main body of the FGSC collection is 19,900 Neurospora strains and this is appropriate given that the FGSC was initially established to assure that the materials used in the demonstration of the seminal one-gene one-enzyme hypothesis (Beadle and Tatum, 1941) would be available to future generations of researchers. As the FGSC is currently in it's 15 y of operation, it is clear that this has been successful. Any assessment of the impact that Neurospora has had on the advancement of scientific knowledge cannot ignore the impact made by the generally unrestricted access to qualified biological materials by the FGSC. Another indication of this impact is the continued growth of the FGSC collection. Continued success has led to continued growth, and this growth is not just limited to Neurospora. The organism with the second largest number of strains is *Aspergillus nidulans* and deposits of *A. nidulans* began in October 1962. The growth of the Aspergillus collection has not kept pace with the growth of the Neurospora collection and this can be traced in part to the unwillingness of the founders of Aspergillus genetics to share materials.

This notwithstanding, over 325 people have deposited strains into the FGSC collection and 70 individuals have deposited one strain each. Similarly over 210 people have deposited more than one but fewer than ten strains. Dr. D.D. Perkins deposited over 3000 strains although this occurred over a period of more than 45 y. The first active strain he deposited was FGSC 2, a *thr-2* mutant accessioned into the FGSC collection on July 11, 1960 (FGSC 1, also deposited by Dr. Perkins, was retired in 1964 because it carried 'aberrations'), and the last strain he deposited was FGSC 10003, a complicated heterokaryon strain used for characterizing chromosome duplications, which was deposited in December 2005.

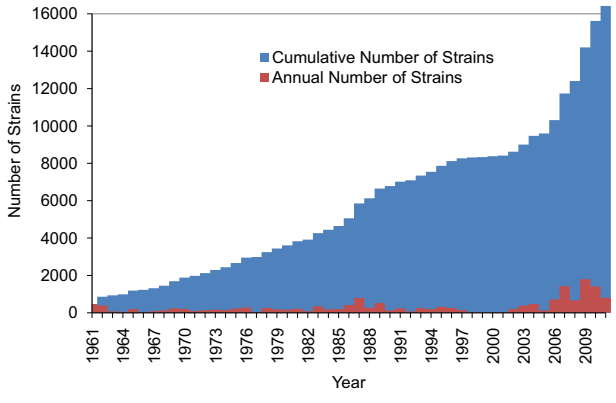

Fig. 1 – Deposits to the FGSC and the cumulative growth of the collection.

While over 325 people have deposited strains, much of the growth shown in Fig. 1 is accomplished by large deposits. For example, the series of large deposits since 2005 are comprised the Neurospora gene deletion mutants produced by the Neurospora and subsequent filamentous fungal program project grants (Colot *et al.*, 2006). Similarly, in the late 1990s the FGSC received a large number of wild-type Neurospora isolates from the collection of Dr. D.D. Perkins (Turner *et al.*, 2001). These wild isolates are proving to be very interesting and have been found to harbor a variety of traits, for example the suppression of meiotic silencing (Kasbekar *et al.*, 2011).

Concomitant with the growth in deposits, the FGSC has seen a significant rise in distribution (Fig. 2). The significant growth in distribution that began in 2005 is reflective of the availability of mutants in genes not previously represented by mutants. This was made possible by the generation and deposit of gene deletion mutant strains for nearly every gene in *Neurospora crassa* (Colot *et al.*, 2006). Prior to the activities of the functional genomics program, mutants were only available for approximately 1200 genes (Perkins *et al.*, 2001). Now with over 11,000 gene deletion mutants, most genes are represented by mutants. Because of how these mutant strains are generated, there are two different superficial ways to measure the phenotypic impact of the gene deletion. The first is the ability to generate a haploid gene deletion strain and 9881 strains were deposited as haploid homokaryons. The second is the ability to grow the strain for preservation and of these fewer than 100 of these haploid homokaryons have a phenotype that impacts their ability to grow and sporulate on agar solidified minimal medium.

As part of the functional genomics program, we have prepared spore suspensions for each *N. crassa* gene deletion mutant and arrayed them in 96-well format. To do this we have had to develop techniques for handling strains in a high-throughput manner and several key innovations were important in enabling this. One such innovation is the dispensing of a layer of sterile milk foam above the surface of the conidiating culture growing on agar solidified medium in a culture slant. This layer of foam allows passage of the transfer pipette but does not allow airborne spores to leave the tube and allows for the handling of many strains in one sitting. We have also employed a 96-channel pipetting system capable of pipetting up to 500 ml. Finally, we tested the ability to freeze and thaw cryopreserved *N. crassa* strains and found that while multiple cycles of freezing and thawing did reduce the numbers of viable propagules, this reduction did not impact our ability to recover viable conidia in good numbers (McCluskey *et al.*, 2006).

Similarly, the FGSC has taken on large numbers of Candida and Cryptococcus mutants arrayed in 96-well format. Since the deposit of these arrayed mutant sets began in 2005, the

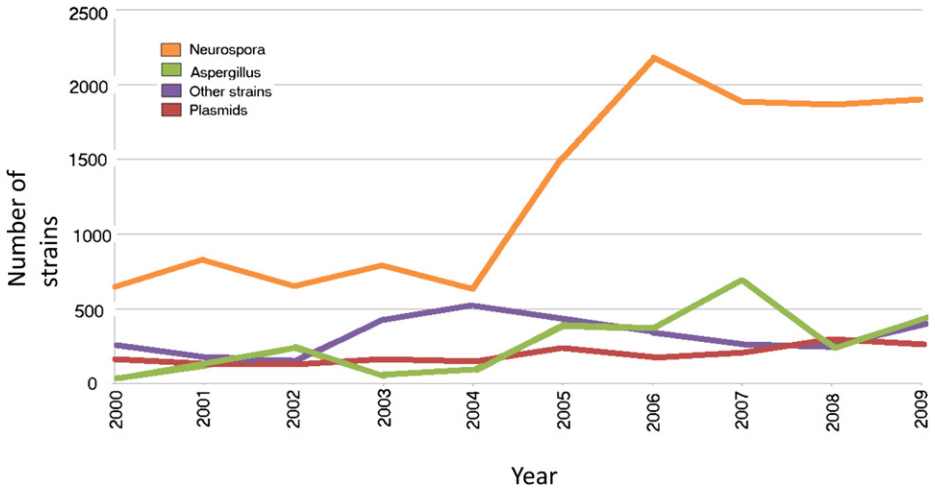

Fig. 2 – Distribution of materials from the FGSC from 2000 to 2009.

FGSC has distributed well over half a million strains in this format. This is similar in scope to the numbers of genomic library clones distributed by the FGSC beginning in the late 1980s. In addition to gene and genome libraries, the FGSC has taken on the responsibility of distributing molecular materials including plasmids (Fig. 2), *A. nidulans* gene deletion cassettes, genomic DNA and reagents for working with Aspergillus, Neurospora and other filamentous fungi.

In addition to the molecular materials, a growing majority of strains in the collection are genetically engineered. This is seen both in the numbers of strains in the collection as well as in the numbers of strains distributed (Fig. 3). Prior to 2005, the majority of strains both in the collection and distributed by the FGSC were classical mutants or wild-type strains. For strains distributed individually, the fraction which were generated by genetically engineering reached approximately 55 % in 2005 and has stayed above 50 % since then. This does not include the hundreds of thousands of strains distributed as arrayed sets and which would reduce the fraction of classical mutants or wild types distributed to below 5 % for the last 5 y. The importance of this cannot be stressed enough as the laws governing distribution of GMO fungi, especially plant or human pathogens, have not been modified to accommodate the development of this technology.

Finally, the FGSC has been called an open source repository because it does not claim intellectual property rights for the materials in the collection. The FGSC uses a "click-through" Material Transfer Agreement whereby entering a material request *via* the FGSC website includes acceptance of the following terms: "The recipient agrees to acknowledge the FGSC in any publications arising from work with the materials and to arrange payment of the FGSC invoice." Other collections manage the intellectual property rights of the materials in their collection more aggressively. The FGSC, being comprised two full-time and additional part-time staff, is not in a position to monitor intellectual property rights of the depositors. In recognition of this the FGSC restricts distribution of molecular genetic materials to non-profit entities. This is a position that is becoming more common among collections that do not have the resources to have an in-house intellectual property division. Interestingly, the materials in the collection are not equally attractive to for-profit entities (Fig. 4). Of the materials distributed in the last 10 y, less than 12 % of all materials were sent to for-profit entities and the materials most commonly used by for-profit entities were Aspergillus strains. In order to encourage deposit of useful plasmids, the FGSC advisory board changed policy to restrict distribution of plasmids to non-profit entities. Nevertheless, in the last 10 y, the fraction of plasmids sent to for-profit entities is second only to Aspergillus strains.

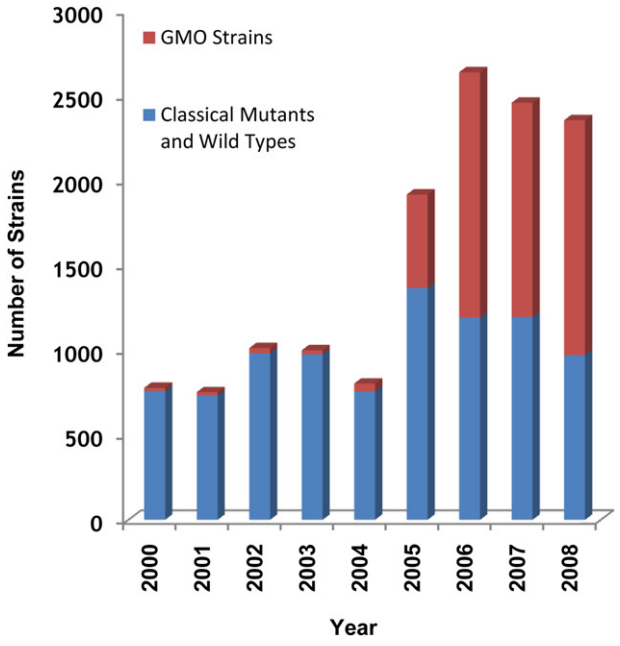

Fig. 3 – Distribution of genetically modified strains from 2000 to 2008. The total number of strains distributed (not including strains distributed as part of arrayed sets) is shown on the vertical axis. The fraction that were genetically modified is shown in the red area at the top of each bar.

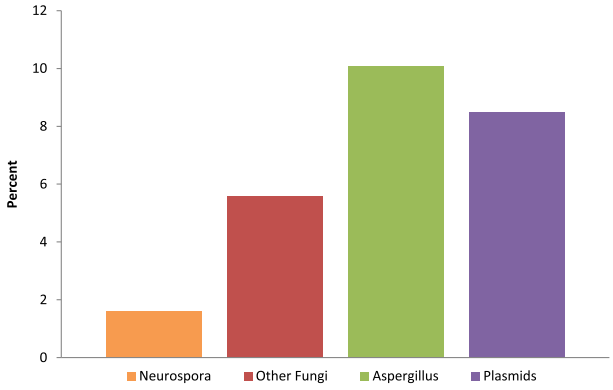

Fig. 4 – The percentage of material sent to for-profit clients, by material type from 2000 to 2010.

Overall, the FGSC manages to distribute thousands of strains, clones, and arrayed sets to clients all over the world and does this with a very small budget. The FGSC collection continues to grow, reflective of the good reputation it enjoys in the research community it serves. Moreover, the FGSC leverages the investment made by the US National Science Foundation to make a significant and enduring impact on ongoing research with filamentous fungi.

3. Global *ex situ* fungal germplasm collections

Because of the recognized importance of access to validated fungal germplasm, many countries have established independent *ex situ* repositories dedicated to or emphasizing fungi (Table 1). Among these repositories are large Biological Resource Centers, such as the American Type Culture Collection in the US, the Centraalbureau voor Schimmelcultures in the Netherlands, and the Deutsche Sammlung von Mikroorganismen und Zellkulturen in Germany. These are among the largest *ex situ* repositories in existence and all have extensive holdings including organisms from every branch of life (Stackebrandt, 2010). These collections are significantly focused on taxonomy and indeed, this is evident from both their emphases and their publications. These major collections are generally supported by their national government, although in the USA, the ATCC has to recover most of it's costs by charging fees for the materials they distribute. One important goal of having a national or regional collection is to allow access to and to generate benefit from the microbial diversity of a country or region. Indeed, the convention on biological diversity has established as part of the so-called Nagoya Protocol, guidelines for access and benefit sharing.

Similarly, there is another category of *ex situ* microbial germplasm repository whose emphasis is materials that are covered by patents. These collections, called International Patent Depositories (IDA) under the 1977 Budapest Treaty on the International Recognition of the Deposit of Microorganisms for the Purposes of Patent Procedure, often operate in parallel with other collections. The USA has two IDAs, one at the ATCC and the other at the US Department of Agriculture collection in Peoria, Illinois, while other countries often have only one IDA. Many countries have IDAs and as of 2010 there were thirty eight IDAs in twenty one countries. There are no IDAs in Africa, the middle east, or among the countries of the pacific ocean, although materials may be deposited in an IDA other than that of the host country of an inventor. In order to be considered an IDA, a collection must be able to make assurances as to their ability to provide services required of such a collection. Among these are external evaluations, documented financial support, committed staff, and a physical infrastructure compatible with long-term operation of a microbial germplasm repository.

While IDAs may be rare, data from the World Federation for Culture Collections' World Data Centre for Microorganisms document nearly 600 culture collections around the world. Of these, 235 report that they are funded by their national or state government and just over 200 of them are university based. It is estimated that over three thousand people work at these collections, and that these people are outnumbered by over five hundred to one by the cultures in the collections. Estimates by the WDCM suggest that over 500,000, or nearly one-third, of the isolates in these collections are fungal and that over 25,000 species or sub-species are represented in these collections. Their data go on to describe eleven culture collections in Africa, two hundred culture collections each in Asia and Europe, nearly one hundred culture collections in South and Latin America and only forty culture collections in North America. While these data are self-reported, they show that the USA is eighth in the total number of culture collections, behind such powerhouses as Brazil, France, India, Japan and China. Twelve countries report having only one culture collection each while seventeen countries report having over ten culture collections.

4. National and international networks of *ex situ* germplasm collections

Because collections often have international impact, researchers have endeavored to formalize their interactions by banding together in federations and associations. The most significant of these is the World Federation for Culture Collections (WFCC) which was established in the 1960s as a multidisciplinary commission of the International Union of Biological Sciences. The WFCC is additionally a federation under the umbrella of the International Union of Microbiological Sciences (IUMS) and as such participates in IUMS activities and shares IUMS goals including the promotion of international cooperation, the exchange of scientific information, and the promotion of world peace. Among the extant networks of microbial germplasm repositories, some are geographically limited, such as the UNKCC, the FELAC, or the now-defunct USFCC, while others are global in scope. Among the latter networks are the WFCC and the GBRCN (Table 2). Similarly, collections of biological specimens are being organized under the banner of the International Society of Biological and Environmental Repositories. Collections allied with ISBER are more likely to be tissue or seed banks and ISBER does not have a culture collection division. ISBER was established as a division of the American Society for Experimental Pathology, reflective of its emphasis on tissue or specimen storage.

Because of the importance of access to biological material, scientists in other disciplines, such as computer science, economics, and law, study this topic. The tremendous wealth of data about individual isolates in culture collections has led to the development of algorithm based electronic systems for managing and mining this information. One such system, known as 'straininfo.net' provides a database mining system that provides both the location of individual isolates, and the cross-referencing of data for isolates held in multiple collections (Verslyppe *et al.*, 2011). Other impact from this inter-disciplinary cross-fertilization includes evaluations of legal and economic impact of collections.

5. Policy impacting collections

Efforts to develop best practice guidelines got a kick-start when the Organization for Economic Cooperation and Development (OECD) published their best practice guidelines (2007). For a modern microbiological laboratory, the guidelines are as much about record keeping as they are about specific practices. Nevertheless, while they assume that adequate expertise exists, they emphasize the development and implementation of standard operating practices as well as key factors regarding the facility design as it impacts the ability to carry out the operations necessary for a Biological Resource Center. Among them are chapters on the function of a Biological Resource Center, the assessments necessary for development of best practices, specific practices for laboratory manipulations, record keeping, client management and biosecurity issues.

Another advance to the cause of culture collection support and maintenance came in 2010 when the US Office of Science and Technology Policy (OSTP) issued a statement supporting collection science generally and made specific recommendations for the continued support of collections. These included institutionalizing support for collections and for increasing publicity about collections. This is important both because of what it says and because of who says it. The OSTP is officially part of the office of the President of the US and presumably this means that the president is at least at some level aware of the existence of collections.

Management of intellectual property rights is a continuing challenge for culture collections. While some collections, such as the FGSC, are very open with their materials, others aggressively manage the rights associated with the materials they distribute. An effort to develop standards for exchange of microbial materials, known as the microbial commons (Dedeurwaerdere, 2010), is associated with the development of uniform standards and language for open exchange of materials. Many collections now use a document referred to as the Uniform Biological Material Transfer Agreement (UBMTA) which is available from a number of websites. As mentioned above, the FGSC uses a click-through MTA where clients agree to cite the FGSC. Additional burdens that fall disproportionately on smaller collections include the requirement for local permits, the certification of equipment and the growing trend toward external certification, such as ISO 9001 certification. While best practice guidelines, such as that by the OECD or the ISBER, contribute toward the development of uniformity in the culture collection community, they are in some ways unfunded mandates. The cost of implementing some best practices, especially for external certifications, is prohibitive for small collections and may drive the consolidation of collections. This runs counter to the wishes of many scientists who see large consolidated central repositories as being non-responsive and monolithic. This notwithstanding, centralized administration is the trend and lends support to the rationale supporting the development of federations of collections.

The valuation of biological materials is an area where no logical system has been adopted. This is a question of some importance for international exchange of biological materials. It is difficult to assign a uniform value to a fungal strain and different values are often applied to the same materials by different collections. For example, one sample of *A. nidulans* FGSC A4 from the FGSC is $20 and the same strain from the ATCC is $275 and from CBS €150. When the ability to gain access to materials depends on the client's ability to pay often excessive import fees, it becomes desirable to declare a lower value. Alternatively, governments could agree that microbial germplasm used for non-profit research should be exempt from import duties and taxes. Most international negotiations in this area, such as the convention on biological diversity, focus on providing a framework for linking benefit sharing with access to biological materials and little attention is paid to the logistics of distribution.

Similarly, regulations governing postal and express courier transportation of biological materials evolve very slowly and organizations such as the WFCC have an important role. Recent reviews of shipping regulations sought to classify microbial cultures as "un-natural concentrations" of microbes, but this language was stricken from the final regulations because of input from collections scientists. Additional policies, embodied in a number of best practice guidelines, dictate that materials should not be sent to residential addresses, nor to anonymous third-parties. Moreover these same guidelines dictate that packages containing biological materials should be shipped with a tracking number and not as first-class or parcel post mail.

6. Impact of collections

Because of the highly diverse nature of materials in *ex situ* repositories, it is difficult to quantify the impact of these materials. Simply tracking citations to collections gives some insight into the impact of collections, but a quantitative analysis of the impact has long been lacking. Furman and Stern, using a difference in differences approach, have shown that materials in collections can have as much as twice as many citations as similar materials that are held in the laboratory of origin, and that this impact is double for materials deposited by investigators from smaller universities or institutes (Furman and Stern, 2011). The FGSC has maintained a record of citations and with the advent of searchable online databases has collected this information (Fig. 5). These citations have grown over recent years to over 200 per year. Additional impact is evident when one investigates the nature of these citations. Materials in the FGSC collection have included

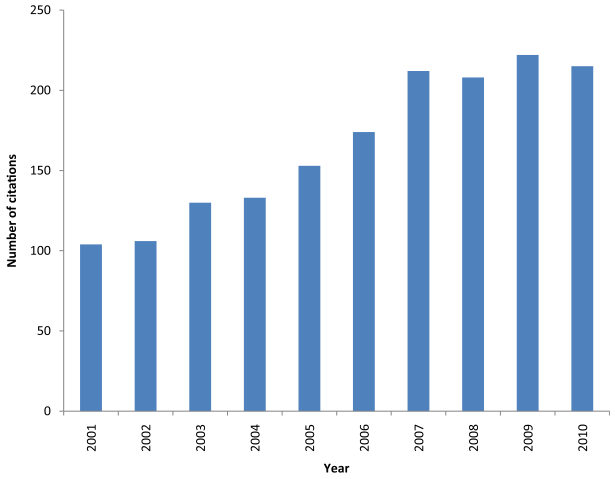

Fig. 5 – The growth of citations to materials from the FGSC collection from 2001 to 2010. Data are from date limited searches using "Google Scholar" search with "FGSC" or "Fungal Genetics Stock Center" as the search term.

genome libraries with the published locations of many genes as well as genome-sequence associated libraries. Other collections of materials include cDNA libraries and arrayed mutant collections. These materials leverage the work of previous researchers in an unprecedented manner. One e-mail or a click on a web-page can provide the biological material which will allow a researcher to access genes, or a region of the genome, with unprecedented rapidity.

In years past, the pace of repository activities was glacial. Often multiple letters or cards would be exchanged including a general inquiry of the collection curator, followed by a description of the materials which might satisfy the needs of the client. This would culminate in a material request and ultimately a shipment to the client. This could take anywhere from several weeks to several months. Modern science proceeds at a frenzied pace, by comparison. Most collections list their catalogs at sites on the internet (Table 3) and material requests can be placed, payment made, and materials dispatched often within the same day. With the advent of express courier services, such as FedEx, UPS or DHL, materials can even be delivered to the client on the day following their initial inquiry.

Further highlighting the potential for adding value by depositing materials in a collection, the depositing researcher may not anticipate the use to which materials will be put. This was certainly the case for mutant strains of Neurospora which were characterized as being osmotically sensitive. Strains carrying the mutation *os-2* were sensitive to high salt conditions (Perkins *et al.*, 1969). Subsequent work showed that these strains were also resistant to phenylpyrrole fungicides (Zhang *et al.*, 2002) and after this work was published strains carrying the *os-2* mutation became the most often requested strains in the FGSC collection (McCluskey and Plamann, 2008). Similar examples exist for most collections. It is certainly true for materials as diverse as penicillium producing fungi or extremophile polymerase enzymes (Dugan *et al.*, 2011). The impact of these two organisms, while individually small, is enormous when the industries that have grown out of original observations are considered. Whether the "next big thing" will come from materials in the FGSC collection, or from another of the many global *ex situ* fungal germplasm repositories cannot be known. What is certain is that *ex situ* microbial germplasm repositories will continue to have an impact on every aspect of science and industry.

Table 3 – Websites of fungal germplasm repositories

North America	
FGSC	http://www.fgsc.net
FRL	http://frc.cas.psu.edu/
NRRL	http://nrrl.ncaur.usda.gov/
FPL	http://www.fpl.fs.fed.us/research/centers/mycology/culture-collection.shtml
INVAM	http://invam.caf.wvu.edu/
ARSEF	http://www.ars.usda.gov/Main/docs.htm?%fdocid=12125
Pfaff	http://www.phaffcollection.org/
WPC	http://phytophthora.ucr.edu
ATCC	http://www.atcc.org/
UAMH	http://www.devonian2.ualberta.ca/uamh/
Latin America	
SiCol	http://sicol.cria.org.br/
Europe	
CBS	http://www.cbs.knaw.nl/
DSMZ	http://www.dsmz.de/
BCCM MUCL	http://bccm.belspo.be/index.php
DTU	http://fbd.dtu.dk/straincollection/
VTT	http://culturecollection.vtt.fi/
UKNCC	http://www.ukncc.co.uk/
MUM	http://www.micoteca.deb.uminho.pt/
VKM	http://www.vkm.ru/
Asia	
KBRC	http://www.brc.re.kr/English/Intro.aspx
Nite	http://www.nbrc.nite.go.jp/e/index.html
ACCC	http://www.accc.org.cn/show.asp?uver=cn
IMCAS	http://www.im.ac.cn/english1/supporting_systems/1.htm

Acknowledgment

The FGSC is supported by grant 742713 from the US National Science Foundation.

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