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From genetics to genomics: fungal collections at the Fungal Genetics Stock Center

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The Fungal Genetics Stock Center (FGSC) has been described as an Open Source Repository supporting over 50 years of research into some of the most fundamental questions in modern biology. From its origins allied to studies of the nature of genes, through the first efforts to associate DNA sequence with genes, to its current position as a repository for nearly 75 strains with fully sequenced genomes, the FGSC has taken on whatever challenges the community has offered. As the tools have changed over the years the FGSC has adapted. Whether it was classical mutants, gene libraries, or fully genome-sequenced strains, and even gene deletion sets for several fungi, the FGSC community has trusted their most valuable resources to the FGSC. The FGSC currently holds nearly 20,000 accessioned fungal strains. Additional non-accessioned strains, including Cryptococcus and Candida deletion sets, Magnaporthe-tagged integrants, lyophilized strains from the Tatum collection, and wild strains from the Perkins lab, bring the total number of fungal strains held at the FGSC to over 75,000. History has shown that shared resources are more valuable and the communities that shared the most, gained the most. The resources in the collection at the FGSC have reiterated and emphasized this by acting as the rising tide that has lifted the boat of fungal genetics, and fungal genomics, research.

Keywords: Neurospora; Aspergillus; Biological Resource Center; classical mutant; whole genome sequence

From genetics to genomics: fungal collections at the Fungal Genetics Stock Center

The Fungal Genetics Stock Center (FGSC) was founded in 1960 when the US National Science Foundation (NSF) made a grant to Dr. Raymond Barratt at Dartmouth College for “Collection and Maintenance of Genetic Stocks of Neurospora crassa and Aspergillus nidulans.” This proposal was in response to the results of a survey conducted by the Genetics Society of America Committee on Maintenance of Genetic Stocks which indicated that there were 21 laboratories working with Neurospora. The respondents to this survey indicated that there were approximately 9000 strains being maintained by the different laboratories. The proposal estimated that somewhere between 1000 and 2000 Neurospora and 350 A. nidulans stocks would be sufficient to represent all the important material being used for genetic research at the time. They further indicated that there were approximately 120 genetic loci being studied in Neurospora and that “no other filamentous fungi are sufficiently widely in use at the present time to merit inclusion in the stock culture center; although, Venturia, various species of Fusarium, Glomerella, Schizophyllum, and Sordaria” were also being used for genetic analysis by laboratories around the world.

The establishment of the FGSC was also spurred by the Nobel Prize being awarded, in 1958, to Beadle and Tatum for their work on what has become known as the “one gene–one enzyme hypothesis” (Beadle and Tatum 1941). In the ensuing 50 years, the FGSC has grown beyond the imagination of most conservative researchers to include nearly 20,000 accessioned strains and as many as 60,000 non-accessioned strains of fungi including Neurospora, Aspergillus, Fusarium, Schizophyllum, Sordaria, Magnaporthe, Cryptococcus, and Candida. Other genera represented by genome strains include Verticillium, Trichoderma, Ustilago, Coprinopsis, Ashbya, Colletotrichum, and others (McCluskey 2003). Perhaps more importantly, the genetic breadth of the collection has grown tremendously. This is aided by the dual and complementary advances in genome sequencing and gene disruption technology. As to genomics, the FGSC collection includes over 75 strains that have had their genomes sequenced. These strains represent 31 different species. Finally, the FGSC has always adapted to keep pace with developments in technology. When available technology demanded access to genetic libraries, the FGSC accepted and distributed libraries. When cloning and transformation vectors became useful, the FGSC took on the task of maintaining and distributing them. When fluorescently tagged and epitope-tagged vectors became useful, we obtained and distributed these. When gene deletion sets became possible (Colot et al. 2006), we arrayed or accepted sets and
increased our strain distribution from 1000 per year to over 100,000 per year. While it is not possible to say what technological advancement will come in the future, the FGSC has a history of adapting to technological advancements and amplifying their adaption in the research community. As much as the FGSC has been a collection of good model organisms, it has become a model of a good collection.

Many collections of filamentous fungi exist in the United States (Table 1) and span the range from small and focused, like the International Vesicular-Arbuscular Mycorrhizal Fungus Collection at West Virginia University, to mission oriented, like the Entomopathogenic Fungus Collection at the Boyce Thompson Institute, to large and diverse, such as the US Department of Agriculture (USDA) collection at Peoria, IL, USA or the American Type Culture Collection in Rockville, MD, USA.

The FGSC has always been unusual among culture collections. Most collections might have a few isolates of thousands of species whereas the FGSC has from the very beginning had only a few species in the collection. This is typical, however, of genetic stock centers. The NSF supports genetic stock centers for a variety of different organisms, including Bacillus, Escherichia coli, and Chlamydomonas, as well as larger organisms, such as Drosophila, mice, and even primates. Each of these collections is narrow in its focus and integrated into their specific research community. Like each of these collections, the FGSC has an external advisory board that is made up of US scientists from each of the research communities the FGSC serves. These scientists visit the FGSC every year to assure that we are meeting our goals. This is mandated by the NSF and helps provide continuity to the FGSC.

The FGSC has moved three times. The first time it moved from Dartmouth to the California State College at Humboldt. It moved when the Director, Raymond Barratt took a position as Dean of the College of Science there. The second move came in 1985 when Dr. Barratt retired as Director and it saw the FGSC moving from California to the University of Kansas Medical Center (KU Med) in Kansas City, Kansas where John A. Kinsey became the new Director. Along with the collection, Craig H. Wilson moved with the FGSC from California to Kansas where he continued as Curator until 1995. The FGSC stayed at KU Med Center until Dr. Kinsey retired and at that time it moved across state line to the University of Missouri-Kansas City (UMKC). This move was the most complicated, as the FGSC had grown to include significant molecular resources and cryopreservation equipment. Another issue was the movement of materials covered by permits from the USDA, Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine division as well as the USDA APHIS Biotechnology Regulatory Service. The former permits cover plant pathogenic organism while the latter are required for genetically engineered plant pathogens. The new home of the FGSC in the School of Biological Sciences at UMKC includes a larger lab, dedicated transfer room, and separate office space. The UMKC School of Biological Sciences remodeled the space currently occupied by the FGSC specifically to suit our unique needs. Unlike most labs which need bench space and cabinets, the FGSC needs wall space, electrical power, and good cooling. Our equipment currently includes four −80°C freezers, two −20°C freezers, six large refrigerators, and several incubators and ovens. All of this equipment generates a significant amount of heat emphasizing our need for reliable air conditioning. Also new since moving to UMKC, the FGSC lab is required to be physically inspected by the USDA prior to our receiving permits for plant pathogenic microorganisms. This has been very important because research with filamentous fungi has become both more genetic and more molecular, the FGSC has grown to include a broader variety of organisms.

Table 1. Collections of filamentous fungi in the United States.

| Name                           | Acronym | Type of collection                  | Size  | Location          | Support         |
|--------------------------------|---------|-------------------------------------|-------|-------------------|-----------------|
| American Type Culture Collection | ATCC    | Patent, service, safe deposit       | Large | Rockville, MD     | NIH, NSF        |
| Northern Regional Research Laboratory | NRRL | Patent, service, safe deposit       | Large | Peoria, IL        | USDA            |
| International Culture Collection of (Vesicular) Arbuscular Mycorrhizal Fungi | INVAM | Service                             | Small | Evansdale, WV     | NSF             |
| ARS Collection of Entomopathogenic Fungal Cultures | ARSEF | Service                             | Small | Ithaca, NY        | USDA            |
| Fungal Genetics Stock Center | FGSC    | Service, research                    | Medium| Kansas City, MO   | NSF             |
| Fusarium Research Center       | FRC     | Service, research                    | Medium| University Park, PA| State           |
| Forest Product Laboratory-Center For Forest Mycology Research | FPL-CFM | Service, research                    | Medium| Madison, WI       | USDA            |
Growth of holdings

Over the first several decades, the FGSC collection grew steadily and by 1979 the collection included over 3500 strains (Table 2). This growth continued and in 1999 the collection numbered over 8000 strains. Since moving to UMKC in 2004, the collection has more than doubled the numbers of strains accessioned. This has also included a growth from holding a very limited number of strains, with most diversity associated with *Neurospora* relatives in the Sordariales, to holding a broad range of organisms representing the diversity of fungi that have had their genomes sequenced. In 1970 there were 13 species that were represented in the collection with 8 being *Neurospora* species. By 2009 there were representatives of 113 species in the collection with over 30 being represented by strains that have had their genomes sequenced. Part of this growth has been the recognition that research with an organism can be considered to be genetic if the organism is amenable to molecular genetic manipulation or if it has had its genome sequenced. Prior to these latter developments, strains were only accepted for deposit into the collection if they were used in genetic research, or if they were related to the main organisms in the collection, *Neurospora* or *Aspergillus*.

Deposits to the FGSC collection occur in several categories. Historically, most strains were deposited by individual researchers who recognize the value of including their strains in a publically open collection. Additionally, most journals require that strains be made available or be deposited in public collections. Anyone can make a deposit into the FGSC collection, although not all materials are appropriate for acceptance. The individual who wishes to make a deposit should contact the FGSC staff and describe the materials as well as the relevant publications. There is no fee for depositing materials into the collection, and the FGSC does not manage intellectual property rights on behalf of the depositor. Moreover, the FGSC is not a general collection of wild isolates, but rather emphasizes fungi with genetic application. Over 300 different individuals have deposited strains into the FGSC collection and over 200 of these researchers have deposited fewer than 10 strains each. The late Dr. David Perkins of Stanford University deposited the most strains by a single individual, having sent over 3000 strains to the FGSC. The *Neurospora* Functional Genomics Program has deposited the most strains by a single organization, having generated and deposited over 10,000 gene deletion strains (Colot et al. 2006; Dunlap et al. 2007). Recent growth in deposits of *Aspergillus* strains is the result of a similar community-wide effort that has culminated in the availability of gene deletion cassettes for *A. nidulans*. It is hoped that large numbers of gene deletion strains of *A. nidulans* will be deposited into the FGSC collection by 2015. This is relevant for a number of reasons. Over the last several years there has been a trend toward more deposits by fewer people. Another way to see this is that more strains have been deposited as part of large sets than are deposited individually (Figure 1). One example of such a group of strains is the wild *Neurospora* strains that were collected outside what was considered its traditional range (Jacobson et al. 2006). Another example of this is the collection of *Schizophyllum commune* strains at the FGSC (Raper and Fowler 2004). The 253 strains that makeup this collection were transferred to the FGSC upon the retirement of Dr. C. Raper from the University of Vermont and represent the diversity of mating-type genes from wild and laboratory strains of *S. commune*. In addition to mating-type testers, this collection includes strains with mutations in amino acid, nucleoside, and vitamin biosynthesis as well as the *Schizophyllum* genome strain (Ohm et al. 2010).

FGSC holdings are divided into several categories. Most strains are deposited into the main collections and these strains receive an FGSC accession number. They remain on the active strain list for 10 years and at that point, if they have not been ordered, they become archival. Strains that are ordered often will remain active as long as they are requested. The only difference between archival and active strains is that archival strains are not subject to the same periodic strain testing as are active strains. In general, strains are tested at least every 5 years to assure that they are viable, that they are the correct mating type, and to the extent possible that they have the correct genotype. This results in large database of both longevity and characteristics that may be associated with the longevity of preserved materials. For example, the FGSC currently has 158 silica gel stocks (Wilson 1986) of *Neurospora* strains that were prepared in 1960. Of these, 62 have been ordered since 2000. Among the oldest known viable silica gel stocks, a sample of FGSC 346 was preserved on 27 October 1960 and was viable when sent to a client on 14 July 2010, nearly 50 years later. Similar data exist for lyophilized stocks (Barratt and Tatum 1950). The oldest stocks that have been tested for viability are over 46 years old. Not all specimens at the FGSC are subject to the same handling and some strains at the FGSC are accepted on an as-is basis where we agree to receive the preserved material and distribute strains if people request them. These strains are not part of the main FGSC collection and include historical as well as active materials. In the first category, the FGSC holds significant numbers of freeze-dried spores in vacuum-sealed

Table 2. Growth of the FGSC collection, by decade.

| Year | Number of strains in FGSC collection |
|------|-------------------------------------|
| 1969 | 1888                                |
| 1979 | 3607                                |
| 1989 | 6782                                |
| 1999 | 8380                                |
| 2009 | 15,619                              |
ampoules from the Tatum collection (Barratt 1986). This category also includes lyophilized *Ustilago maydis* samples and silica gel stocks from the collections of Dr. D. Perkins, Dr. F.J. deSerres, Dr. Etta Kafer, among others. Additional non-accessioned materials include filter paper stocks of *Allomyces* from the collection of R. Emerson (Olson 1984) and a tagged integrant collection of *Magnaporthe* totaling nearly 50,000 stocks (Betts et al. 2007). Some of these collections are of more value than others. For example, the collection from D. Perkins includes strains from all over the world and while many have been accessioned into the FGSC collection, many have not been. This collection of wild strains has been described in publications (Turner et al. 2001) and is well used in the population genetic research community (e.g., Villalta et al. 2009). The non-accessioned materials also provide insight into the practices used in the early years of research with filamentous fungi. For example, while the *Ustilago* samples from the early work of D. Perkins may not be valuable for their biological characteristics, each ampoule is hand etched with a strain name and a date. Because of this, it is easy to look back and see that Dr. Perkins was preparing ampoules, for example, on 28 December 1950.

Accepting non-accessioned materials has extended to molecular genetic reagents, including gene libraries and gene deletion sets. Among these materials, the most useful gene libraries were the ordered cosmids libraries. The ordered libraries were of special interest as the cosmids carrying a number of different genes were published in the FGSC catalog beginning in catalog 2 in 1988 and continuing until catalog 10 in 2004 at which time the FGSC catalog was transitioned to online only. The ordered genome libraries for *Neurospora* were also used in assembling the sequenced *Neurospora* genome (Galagan et al. 2003). Other genome-associated libraries have been accepted, including libraries for *Magnaporthe, Batrachochytrium dendrobatidis, S. commune*, and *Puccinia graminis* although there has never been any request for samples from these libraries. Additional molecular reagents include gene deletion collections for *Candida albicans* (Nobile and Mitchell 2009) and for *Cryptococcus neoformans* (Liu et al. 2008). While these are outside the traditional community served by the FGSC, the distribution of these resources represents a meaningful way the FGSC can contribute to ongoing research with fungi.

Among the molecular resources are some that have been de-accessioned. This is a process where we ask the community, via e-mail, on the FGSC website, and by poster presentations at major meetings, if there is any objection to deleting materials from the collection. In 2004, we discarded arrayed cDNA clones for *N. crassa, A. nidulans*, and *C. neoformans* as well as a Yeast Artificial Chromosome library for *N. crassa* (Centola et al. 1994). In the coming years, we anticipate de-accessioning the fosmid libraries from *B. dendrobatidis, S. commune* and *P. graminis*, unless the research communities working with these organisms have a significant justification for maintaining the biological materials in the FGSC collection.

**Distribution**

In the early days of the FGSC collection, most distribution was within the United States with relatively fewer strains being sent to foreign destinations. This is also representative of the number of laboratories working with *Neurospora* in the United States versus those abroad. There were fewer *Neurospora* labs in Europe than there were *Aspergillus* labs. Distribution was also predominantly to non-profit recipients, a trend that continues to the current day. The only requirements that the FGSC imposes on distribution is that the recipient must be at a recognized research institution. Molecular materials are not sent to for-profit clients and no materials are sent for human consumption. During the first 25 years of the FGSC, there
were many clients in high schools (teaching students of 15–18 years of age) where fungi were often used in practical demonstrations of the genetics of auxotrophy, mating, and spor color. For most practical purposes, this is no longer common.

Distribution was modest and documented only on paper deposit forms. In their 1969 application to the NSF for renewal of the FGSC grant, the authors state that “since October 1960, when the stock centre began distributing cultures, over 10,000 stocks have been distributed.” They go on to say that they were distributing over 100 stocks per month and three-fourths of these were to academic research labs and one-quarter were for teaching. More significant was the observation that most stocks had, at that time, been distributed at least once. Currently the FGSC holds many stocks in its archival collection that have never been requested.

Regulations governing distribution of biological organisms have always lagged behind the technology. In the early years, this meant that cultures were shipped in anonymous parcels through the US mail. Most states in the United States, however, acknowledged that *Neurospora* was safe and had no special requirements for shipping. In 2010, *Best Practice Guidelines*, such as those published by the Organization for Economic Cooperation and Development (2007) require that shipments have a tracking number. Moreover, the status of most strains in the collection as genetically engineered means that they need to be packaged as you would package hazardous goods shipments. For shipment of plant and human pathogens, additional safeguards and formal declarations are required. The World Federation for Culture Collections (WFCC) advocates on behalf of culture collections in discussions of shipping regulations. A recent example of the importance of having microbiologists engaged in these discussions was the successful re-evaluation of the definition of a microbial culture to eliminate the statement that cultures were un-natural concentrations of microbial biomass. In 2010 the challenges for shipping microbial material is mostly in identifying the relevant requirements, such as the US Department of Commerce prohibition of the export of “the genetic information to synthesize aflatoxin.” Taken as a whole the proliferation of regulations, and of the agencies enacting them, emphasizes the need for a body, such as the WFCC, to aggregate regulations and make them available to collection staff.

While the FGSC collection has doubled in size since 2005, the numbers of strains distributed has gone up by nearly 100-fold. This is entirely attributable to the availability of gene deletion strains in arrayed format which allows us to send over 10,000 strains in a single shipment. Similarly, the FGSC distributed nearly half a million gene library clones in arrayed sets in the 1980s until the mid-2000s. In total, over 100 libraries were distributed in arrayed sets. Similarly, over 350 cDNA libraries and 126 genomic DNA libraries were distributed as phage suspensions, as transfected *E. coli* cells, or as naked DNA.

The pace of operating the FGSC has changed in recent years as well. In the early years of the collection, clients often exchanged correspondence with the FGSC staff for months prior to receiving the material that they needed for their research. With an Internet-based strain request system, clients can request materials and in some circumstances receive them the next morning. This is only true, of course, for materials that are ready to ship, such as gene libraries or plasmid DNA. The FGSC is unusual among culture collections in that strains are sent as living cultures on agar-solidified medium. Most collections send freeze-dried spores in vacuum-sealed ampoules (Barratt and Tatum 1950). Our policy of sending living cultures is both to allow us to exert quality control on the strains as they leave the FGSC and to allow us to use silica gel stocks which are easier to prepare and can be sampled multiple times (Wilson 1986). From a low level of approximately 300 orders per year in 1994, the number of orders has more than doubled (Figure 2) demonstrating the expanding clientele and continued impact of the FGSC in the research community.

Research at the FGSC

Because the mission of the FGSC is to provide qualified research materials, most of the research done at the FGSC has been related to managing the collection or enhancing the value of materials in the collection. In the early decades, this mostly consisted of strain improvement, largely by backcrossing them into the common laboratory wild-type genetic background. This served multiple purposes. It removed potential second site mutations in strains that were often the result of harsh mutagenesis, and it removed translocations and other genomic rearrangements from the strain background. An additional benefit was that it often meant that mutations originally only present in one mating type would be available in both mating types, simplifying crossing strategies.

The operation of the FGSC is also an ongoing experiment in strain preservation and management. The ability to preserve and revive strains in a variety of formats is tested both explicitly, as when we evaluated the ability of *Neurospora* spores to survive cycles of freezing and thawing (McCluskey et al. 2006), and implicitly, as when we opened and tested ampoules from the Tatum collection in response to a client request (McCluskey 2000; Wilson and Holden 2001). In this latter example, we established that *Neurospora* can survive up to 53 years as lyophilized spores in vacuum-sealed ampoules. Not all strains grew in this test and the characteristics that allowed one sample to remain viable while others that had been preserved more recently were inviable remain unknown. Our periodic strain testing program also provides data on strain viability and our most
recent effort in this regard has demonstrated that *Fusarium* strains can survive both as desiccated spores on silica gel and as cryopreserved spores in 25% glycerol for many years.

Since 1995, however, the main emphasis of the research at the FGSC has been the identification of the gene sequence responsible for otherwise anonymous mutant phenotypes. The first several genes characterized in this manner were temperature-sensitive (ts) lethal mutants, known only by the gene name “unknown,” and the approach used was cosmid walking using complementation of the ts phenotype by selection at 37°C. *un-16* was the first gene identified using this approach (McCluskey et al. 2007), but more recently several other ts-lethal genes have been identified to the level of the DNA sequence (Table 3). The gene *un-16* encodes a ribosomal S9 protein. The mutations in the two ts-lethal alleles of *un-16* are both leucine to arginine mutations (L34R or L103R) and both occur at residues that are conserved from Archaea to mammals. The background reversion frequency of the *un-16* mutant is on the order of one in $10^8$ conidia and because of this, we have developed this as a selectable marker for transformation using complementation with the *Magnaporthe grisea* ortholog to complement the *Neurospora* mutation (Wiest et al. 2009).

Additional ts-lethal mutants that have been characterized (Table 3) have not been as readily amenable to use as selectable markers. For example, *un-7* has a relatively high reversion frequency and was among the most frequent mutants identified in an independent screen (Seiler and Plamann 2003). The high reversion frequency of this mutant and associated mutability of the gene made it difficult to handle, compared to strains carrying the *un-16* mutations. Strains carrying *un-10* and *un-4* were readily transformed to temperature independence with a wild-type copy of their respective open reading frame (ORF). This suggests that the ability to use complementation and selection for temperature independence will be a general feature of ts-lethal mutants. Additional experiments to evaluate the use of this technique for gene disruption are ongoing at the FGSC.

Continuing in this same path, we are seeking to identify, at the level of DNA sequence, many of the remaining anonymous mutants. This is a surprisingly large target, as over 400 genes that have been characterized genetically remain anonymous at the level of the DNA sequence. Among these are mutants with defective morphology, mating, pigmentation, and nutrition. The association of gene sequence with these characteristics will be a significant contribution by the FGSC. The FGSC has established a collaboration with the US Department of Energy, Joint Genome Institute to sequence the whole genome of up to

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**Table 3. Mutants characterized at the FGSC.**

| ts-lethal gene | NCU     | Function     | Reference                  |
|---------------|---------|--------------|----------------------------|
| *un-16*       | NCU01949| Ribosomal S9 protein | McCluskey et al. (2007) |
| *un-10*       | NCU02208| *EIF3B*     | Kinney et al. (2009)       |
| *un-4*        | NCU05515| *tim-16*    | Wiest et al. (2008)        |
| *un-7*        | NCU00652| *png-1*     | Dieterle et al. (2010)     |
25 strains carrying classical mutants. Preliminary analysis of these data was presented at the 2010 Neurospora meeting (McCluskey et al. 2010) and suggests both that this approach will be fruitful and that the comparison of mutant phenotypes with the phenotype of corresponding gene deletion mutants will provide unique insight into gene function. Also among the meaningful accomplishments of this work will be the development of a “consensus” genome allowing evaluation of individual ORFs against a population of gene sequences rather than the simple comparison of one putatively mutated ORF against the reference genome strain. Further impact in the area of genomics will depend on technological advancements. As the cost of sequencing comes down it may be practical to use whole genome sequencing to identify every remaining anonymous mutation among strains in the collection.

Conclusion

The FGSC operates in a context where culture collections are becoming professionalized and are being more widely recognized for the value they provide. Despite the acknowledgement that it is not possible to predict the value of materials in collections, retrospective analyses show that materials in collections can become more valuable when studied with new technologies (McCluskey and Plamann 2008). Recent work by Furman and Stern (2011) has also been able to quantify the impact of depositing materials in publically available collections. This research uses a differences-in-differences approach to evaluate the impact of materials on subsequent publication. It finds that there is a significant increase in citation of materials that are publically available as compared to those that are maintained only in the collection of the original author. The FGSC is, in many ways, an ongoing experiment on the value of depositing materials in a public collection. This is seen both in the growth of the Neurospora collection relative to other organisms, and perhaps more acutely in the impact made by the deposit of molecular reagents into the FGSC collection. Molecular reagents, such as selectable markers and reporter genes, are widely used and allow researchers from unrelated fields to leverage the work done in a model organism system. For example, the plasmid p3SR2 encoding the amdS selectable marker system for Aspergillus (Wernars et al. 1985) has been distributed 38 times and is cited over 200 times. These citations document the use of this selectable marker system in a variety of organisms, including Aspergillus, Colletotrichum, Cochliobolus, Trichoderma, and numerous other fungi. Similarly, the Neurospora expression vector pBARGPE1 (Pall and Brunelli 1993) has been distributed 64 times to researchers in 20 countries and has been used in research with Cercospora, Fusarium, Trametes, and Beauveria in addition to being used by Neurospora researchers. Because these materials are available in the FGSC collection and described in the FGSC catalog, they have a larger impact than they might have had, had they only been described in the original publications describing their use.

The FGSC was established over 50 years ago to serve the growing fungal genetics research community. Strains have been distributed to researchers in over 35 different countries and to most states in the United States. It has followed a path, similar to many culture collections, from a small strain collection to a large integrated biological resource center distributing a wide variety of resources to a broad community of clients. The fact that new communities, such as the plant pathology community in the 1990s and the medical mycology community in the years since 2005, have looked to the FGSC to manage and distribute their research material is a reflection of the good reputation enjoyed by the FGSC around the world. The FGSC has endeavored to both embrace these new resources and to make them available to the broadest range of researchers. To do this, the FGSC staff need to continually learn new techniques and implement new protocols. In a world where science is becoming increasingly professional, the FGSC has managed to be both a collection of model organisms and a model collection of organisms.

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