The Fungal Genetics Stock Center: From Molds to Molecules

KEVIN MCCLUSKEY
FGSC and Department of Microbiology
University of Kansas Medical Center
Kansas City, Kansas 66160

I. Introduction

The Fungal Genetics Stock Center (FGSC) was established in 1960 following the recommendation of the Committee on the Maintenance of Genetic Stocks of the Genetics Society of America (GSA). At this time a number of the scientists who had established fungi in general and *Neurospora* in particular as premier genetic research systems were retiring or planning retirement and it was recognized that important strains needed to be maintained and made available to newer researchers. Moreover, the establishment of a stock center offered the surety that the same strains could be used by researchers in different places and

ADVANCES IN APPLIED MICROBIOLOGY, VOLUME 52

0065-2164/03 $35.00

times. A survey carried out by the GSA found that approximately 9000 *Neurospora* strains were being used around the world and, although the number of duplicated strains or trivial strains was not known, it was suggested that perhaps 1000 to 2000 stocks would be worthy of preservation. It was estimated that there were 21 laboratories using *Neurospora* at the time. A portion of the first grant proposal requesting the funds from the National Science Foundation (NSF) read as follows:

> This proposal seeks support to collect, maintain, publicize, develop and distribute important stocks of *Neurospora* and *Aspergillus* for research and teaching (educational) purposes... Stocks of mutant strains whose genetic analysis has been completed to the location of the locus on one of the seven linkage groups or otherwise published will be included.... Multiple mutants useful for linkage detection and mapping analysis will be developed and maintained. Recurrences at specific loci will be maintained when they have been published on or when other pressing reasons exist. Stocks containing cytoplasmic markers and wild types collected from various locations will be included... Mutant strains on which no genetic analysis has been undertaken will be accepted only when they appear of unusual interest.

This has been the guiding principle of the FGSC throughout its life and, although we have expanded to include other fungi and unanticipated molecular resources, it has been closely adhered to. This, as much as anything else, has contributed to making the FGSC the leading repository for fungal genetic materials in existence.

II. Chronology

The FGSC received support from the NSF and began operations at Dartmouth College under the direction of Dr. Raymond Barratt in July 1960. By the end of the year 469 stocks had been deposited in the collection. This number grew to 866 by the end of 1961 and has continued a similar rate of growth to the present day. Although the bulk of the original strains were mutants, a significant portion of the stocks at the FGSC today are wild-type stocks from around the world. Indeed, recent discoveries have opened new and unexpected areas to collection of wild *Neurospora* strains (Jacobson *et al.*, 2001). The FGSC moved to Humboldt State College in Arcata, California, in August 1970 when Dr. Barratt took a position as dean there. In 1985, Dr. Barratt retired as director and the FGSC moved to the University of Kansas Medical Center where Dr. John Kinsey took over as director. In Kansas City, the FGSC occupies approximately 700 square feet of laboratory space and the director of the collection has a separate laboratory. The FGSC

has proposed, in its pending NSF proposal, to move again in 2004 when Dr. Kinsey retires. The FGSC, with the help of the FGSC advisory board, has selected Dr. Michael Plamann of the University of Missouri, Kansas City (UMKC) to be the next director. This will allow the FGSC to move with a minimum of disruption to its operations. UMKC also offers a convenient and well-located environment for the operations of the FGSC.

III. Organization

The FGSC is comprised of a director, traditionally a researcher working with *Neurospora*, a curator, and two technicians. Drs. Barratt and Kinsey have been the only directors. Mr. Bill Ogata was the original curator and worked with the FGSC until his retirement in 1982. Mr. Craig Wilson took over as curator and moved with the FGSC from Humboldt to Kansas City. He stayed with the FGSC until 1995 when the current curator joined the FGSC. There have been a series of capable technicians at the FGSC over the years.

The FGSC is overseen by an advisory board selected from researchers around the country. They represent a variety of research organisms and areas and meet annually to review the progress of the FGSC and its goals. This group was established in 1999 following the advice of the NSF. Prior to that, the FGSC had used the Fungal Genetics Policy Committee as its guiding body, although the director maintained executive control. The Fungal Genetics Policy Committee (originally the *Neurospora* Policy Committee) is elected at the biannual Fungal Genetics Conference at Asilomar by the conference attendees. The committee balances domestic and international interests as well as the interests of different research emphases.

IV. Context

Most significant research organisms have a collection devoted to maintaining and distributing stocks. The National Science Foundation supports general collections, the National Institutes of Health supports clinically important collections, and the U.S. Department of Agriculture (USDA) supports agriculturally important collections, including plant germ-plasm. The FGSC, one of many culture collections in the United States, distinguishes itself by its involvement in its community and its responsiveness to community needs. Culture collections in general are part of a community connected by the U.S. Federation for Culture Collections in the United States and the World Federation

for Culture Collections (http://www.wfcc.info) internationally. A number of other organizations provide information on the breadth of collections worldwide, including the Microbial Strain Data Network (http://panizzi.shef.ac.uk/msdn/), sponsored by the United Nations, and the World Federation for Culture Collections—MIRCEN World Data Centre for Microorganisms (http://wdcm.nig.ac.jp/).

The FGSC is a genetic collection, and this distinguishes it from many other culture collections. The American Type Culture Collection (Manassas, VA, http://www.atcc.org/) is larger than many other public collections in the United States, but is known for its breadth but not its depth. Another large repository of fungi is the USDA collection at the National Center for Agricultural Utilization Research (originally the Northern Regional Research Laboratory, http://nrrl.ncaur.usda.gov/) in Peoria, Illinois. As this was originally the USDA internal collection, it emphasizes strains with agricultural uses. Many other microbial culture collections exist around the world. The Centraalbureau voor Schimmelcultures (http://www.cbs.knaw.nl/), formerly in Baarn, now in Utrecht, The Netherlands, is notable for its fungal holdings. There are other specialized collections, like the *Fusarium* Research Center at Pennsylvania State University and the *Aspergillus* collection in the laboratory of Dr. A. J. Clutterbuck at Anderson College, Glasgow, UK, but few emphasize the depth of genetic materials that the FGSC does. The Yeast Genetic Stock Center, for many years at University of California at Berkeley, is now part of the ATCC. The Yeast collection is approximately 1200 stocks. Some collections are able to offer custom services, but the small size of the FGSC precludes this.

V. Holdings

A. Neurospora and Aspergillus

The FGSC holds over 16,000 strains, including 9642 strains in the main collection, 3910 strains in the Perkins collection of wild collected *Neurospora* strains (Turner *et al.*, 2001), and various smaller groups of strains that have not received FGSC accession numbers. *Neurospora* forms the bulk of the FGSC collection with 7871 strains in the main collection. Among these are 1417 wild-type strains and 5291 mutant strains. The majority of the *Neurospora* wild-type strains are *N. intermedia* (600 total) with fewer *N. sitophila* (243), *N. crassa* (258), *N. tetrasperma* (164), and *N. discreta* (71) strains. These strains were collected from wild and agricultural sites around the world (Fig. 1)

FIG. 1. Origins of *Neurospora* strains in the FGSC collection.

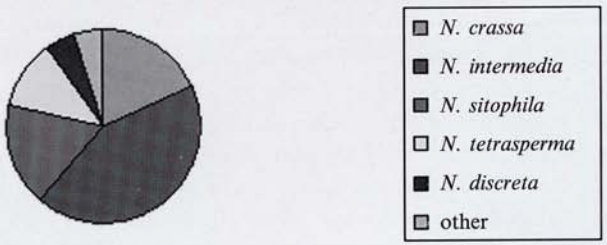

FIG. 2. Different *Neurospora* species in the FGSC collection.

by Dr. D. D. Perkins and others. They were predominantly collected as vegetative colonies from freshly burned substrate. Most have been through serial plating and have been tested by mating with known testers to determine both species and mating type. Most strains have been identified as a specific species and very few are either unknown or considered to be hybrids (Fig. 2).

The *Neurospora* mutant collection, by way of contrast, is primarily made up of *N. crassa* stocks. There are 4729 *N. crassa* mutants

TABLE I

STRAIN CATEGORY

Category of strain	Number of strains
Single mutant strains	3441
Multiple mutant strains	1978
Mitochondrial mutant stocks	85
Wild-type strains	1247
Chromosomal rearrangement stocks	884
Testers and stocks for special purposes	1252

currently active in the collection. These mutants represent over 1700 discrete lesions, including representatives of most of the approximately 1000 genes mapped in *N. crassa* (Perkins *et al.*, 2001). Sixty *N. intermedia* mutants, primarily biosynthetic mutants, 89 *N. tetrasperma* mutant strains, and 17 *N. sitophila* mutant strains comprise the remainder of the *Neurospora* mutant collection (Table I). The *N. crassa* wild-type strain that is most widely used is FGSC #2489 (74-OR23-IVA). This is the strain used by the Whitehead Institute Center for Genome Research (WICGR) to sequence the *N. crassa* genome.

The FGSC holds a number of collections that are part of the FGSC, but whose members do not receive individual FGSC numbers. Among these are the Perkins wild-type strain collection (3910 strains, Turner *et al.*, 2001), Dr. A. Lacy's *trp-3* strains, Dr. J. Fincham's *am* strains, Dr. M. Case's *pan-2* strains, and Dr. R. Davis' polyamine strains. Additional strains are maintained for historical purposes. Of such strains 388 are kept despite being officially retired. A strain may be retired because it is demonstrated to be unstable or to carry secondary mutations. Retired strains are often replaced by backcrossing them with a wild-type strain and the original strain is maintained as a source of the main mutation. The FGSC also has a collection of several hundred lyophils from the E. L. Tatum collection (Barratt, 1986). Certain strains are maintained as groups designed to be used together. Among these are the small and large restriction fragment length polymorphism (RFLP) mapping populations. Other strains are designed for the construction of heterokaryons or for the testing of mutagens, spore killer strains, mating type, or heterokaryon compatibility grouping. The FGSC holds a nearly complete set of known chromosomally abnormal strains. These come largely from the work of Dr. D. D. Perkins (1997). In total, the FGSC holds 842 *Neurospora* stocks with simple translocations, inversions, and duplications.

Some of these are simple, but others are complicated and involve four or more linkage groups. For a detailed description of *Neurospora* research, see Davis (2000). Perkins and Davis (2000) also collaborated on a recent retrospective on *Neurospora* research.

The *Aspergillus* collection is smaller numerically than the *Neurospora* collection. In total, the FGSC holds nearly 2200 *Aspergillus* strains. Of these 1100 are the *Aspergillus nidulans* temperature-sensitive mutant bank developed by Harris and Hamer (Harris *et al.*, 1994). The *A. nidulans* collection is made up of 844 stocks and 124 stocks are *A. niger*. A few *A. awamori*, *A. heterothallicus*, *A. oryzae*, and *A. flavus* stocks complete the *Aspergillus* collection. The FGSC, in cooperation with the *A. fumigatus* sequencing project at Manchester University in Manchester, UK, has recently accepted a strain of *A. fumigatus* pathogenic on humans. Also among the *Aspergillus* strains are 38 wild-type strains from six species and the main *Aspergillus nidulans* wild-type (FGSC A4) in use today. This strain is also the basis of the *A. nidulans* physical map (Prade, 2000). The *A. nidulans* strains include over 800 different genetic lesions at somewhat fewer gene loci. The mutant strains include single mutants as well as strains with all linkage groups marked and special mapping strains to be used as a kit. Other strains are used for targeting heterologous genes among other specialized uses. *Aspergillus* strains are held in a number of collections, largely due to the tremendous industrial importance of fungi in this genus (Jong and Birmingham, 1992).

B. Plant Pathogens

The FGSC *Fusarium* collection consists of mating type and vegetative compatibility group testers as well as strains for RFLP mapping (Xu and Leslie, 1996). Mostly these are *Fusarium moniliforme* but include a number of *F. oxysporum*, *F. graminearum*, and *F. solani* stocks. These are mostly from the collections of Drs. John Leslie, H. C. Kistler, and R. Ploetz. The FGSC *Magnaporthe* collection is comprised entirely of RFLP mapping strains, although it is expected that this will grow to include a large number of targeted gene disruption stocks in the near future.

C. *Sordaria*

The FGSC maintains, at the request of the GSA, a collection of *Sordaria* mutants. These are primarily from the collection of Dr. Y. Kitani and are similar to *Neurospora* in their handling characteristics. In total

there are 230 *Sordaria fimicola* strains and eight *S. brevicollis* stocks. The *S. fimicola* stocks include 46 different loci in five different linkage groups. The FGSC holds two *Sordaria macrospora* stocks.

D. Additional Fungi

Although not part of the main focus of the collection, the FGSC has a small number of other fungi, including *Gelasinospora*, *Podospora*, *Coniochaeta*, *Ascobolus*, and *Apiosordaria*. For the most part, these are type strains and are not genetic collections. They are useful, however, in providing outgroups for various studies. The FGSC also holds a collection of *Allomyces* strains from the collection of Drs. R. Emmerson and L. W. Olson (1984).

E. Molecular Genetic Materials

Since the late 1980s the FGSC has held an increasing number of molecular genetic materials. Originally, this was limited to cloned genes and cloning vectors, but soon included gene libraries for both *Aspergillus* and *Neurospora*. This has had a profound impact on both the relevance of the FGSC and the nature of research with *Aspergillus* and *Neurospora*. For the FGSC, it has maintained the position of the collection as the central resource for materials in fungal genetics. It has also allowed the progress made with these two main organisms to be extended and applied to other fungi. The collection of cloned genes and cloning vectors now numbers 206 with an additional 121 *Fusarium* RFLP markers and 182 RFLP markers for *Magnaporthe grisea*.

Among the 206 vectors and genes are cloning vectors encoding different antibiotic resistance, including benomyl, hygromycin, bialaphos, and sulfonylurea (Sweigard *et al.*, 1997). Other vectors are designed for library construction, DNA expression (Ebbole, 1990), or mutagenesis (Hamer and Gilger, 1997). The growth in the clone collection recently has slowed as more and more people are using clones from the several libraries associated with the genome projects rather than subcloned genes. Most of the information on clone identity is therefore resident on the genome server and not at the FGSC.

The collection of genomic DNA libraries has fostered research in a number of ways. The ordered libraries for *Aspergillus* and *Neurospora* have a great deal of information associated with them. The original *Neurospora* library is the pSV50 library and although it is known to be incomplete, the locations of over 50 genes are published in the FGSC

catalog. Similar information has long been available for the pMOcosX library, which has largely replaced the pSV50 library. The pMOcosX library was also used in the WICGR *Neurospora* genome project along with the pLORIST6xh library. In addition to these, the FGSC also holds an *N. crassa* YAC library, a BAC library, and numerous unordered *N. crassa* genomic libraries in both cosmid and phage vectors. The three *A. nidulans* ordered genome libraries are all related. The main set is the pWE15/pLORIST2 set, which is comprised of 60 96-well plates. Using data from the University of Georgia physical mapping program (Prade *et al.*, 1997), the FGSC picked both chromosome-specific sets and a minimal set from the original set. With the minimal set, the entire genome is represented on 16 96-well plates, with adjacent clones representing adjacent DNA on the chromosomes of *A. nidulans.* Since taking on these libraries, the FGSC has distributed nearly 140 copies in one form or another. The identities of numerous clones in this library are published in the FGSC catalog. The FGSC also holds one genomic library for *A. nidulans* in phage lamdba.

The collection of cDNA libraries for both *Neurospora* and *Aspergillus* is impressive. Although the *Neurospora* libraries outnumber the *Aspergillus* collection, both have been put to good use. The *A. nidulans* 24-h germinated conidia cDNA library was used at the University of Oklahoma as the basis of the *A. nidulans* EST bank (Kupfer, 1999). This library was distributed, in total, 67 times. A recent addition to the FGSC collection, the *A. nidulans* libraries in autonomously replicating vectors have become popular (Osherov *et al.*, 2000).

The *Neurospora* Genome Project (NGP) at the University of New Mexico, under the guidance of Drs. D. Natvig and M. A. Nelson generated a series of cDNA libraries that were made from RNA extracted from tissue in different developmental stages (Nelson *et al.*, 1997). Among these are the mycelial, conidial, and perithecial libraries. These, as well as their two-hybrid versions, have also been well used by the community. Other *N. crassa* cDNA libraries include the expression system for use in yeast or *E. coli* (Brunelli and Pall, 1993) and the nutritional-condition-specific cDNA libraries from Dr. R. Garrett (Exley *et al.*, 1993) and Dr. M. Sachs (Orbach *et al.*, 1990).

For a number of years, the FGSC distributed expressed sequence tag (EST) clones from the NGP and from the University of Oklahoma Advanced Center for Genome Technology. The NGP provided *N. crassa* ESTs from a variety of different tissue and the Oklahoma group provided *A. nidulans* ESTs from the 24-h germinated conidia cDNA library (Kupfer, 1999) and circadian rhythm-specific ESTs (Zhu *et al.*, 2001) from *N. crassa.* For a variety of reasons, including

the ease of generating full-length clones with PCR, the FGSC is no longer distributing ESTs.

VI. Source of Materials

Over 200 individuals have deposited materials into the FGSC collection. Dr. D. D. Perkins of Stanford University has deposited the most, with an impressive 3124 strains to his credit. This is in addition to the strains of the Perkins collection. Dr. F. deSerres deposited the second largest number of strains, with 933 to his credit. These are largely *ad-3B* strains with 439 containing that lesion. He deposited 700 *ad-3* strains in total. Dr. E. Kafer, now at Simon Fraser University, has deposited 829 strains of which 368 are *Neurospora* and the remainder *Aspergillus*. Dr. Kafer has deposited 32 *A. niger* strains out of a total 126 strains of that organism in the collection. She has also served as a consultant for the organization of the *A. niger* section of the FGSC catalog. Drs. J. Leslie, R. L. Metzenberg, M. Case, Y. Kitani, and D. Jacobson have all deposited over 200 strains each. Most of these strains are deposited at the initiative of the investigator, although the FGSC does request specific strains when they are described in the literature.

VII. Preservation

A. Fungal Strains

The FGSC has used proven long-term storage technology throughout its history but, because no one technology is foolproof, the FGSC has a strategy of reliability through redundancy. From the beginning of the collection, the primary means of preserving cultures has been to store them in anhydrous silica gel (Wilson, 1986). This has proven to be a very robust technique, and stocks that were preserved in the early days of the FGSC are still viable. This technique has been shown to preserve the genetic nature of strains (Jong and Davis, 1976). In addition to silica gel, stocks are also kept as lyophilized spores (Wilson, 1986). The record for longevity with *Neurospora* is 54 years (McCluskey, 2000b). Neither of these techniques is very useful for storing strains that do not sporulate profusely. For this reason, morphological mutants are now stored as both −80°C stocks (in 25% glycerol) and above liquid nitrogen (Wilson, 1986). Extending the strategy of reliability through redundancy, and to protect against catastrophic loss of materials, the FGSC maintains backups of certain aspects of the collection. This

applies primarily to primary mutants and wild-type strains. In this light, the *Neurospora* collection is backed up by a set of lyophils that is housed at the University of California, Santa Cruz in the laboratory of Dr. B. Bowman. This collection was stored at Stanford University in the laboratory of Dr. D. D. Perkins until recently. The *Aspergillus* collection is backed up similarly by a set of lyophils at the University of Texas M.D. Anderson Cancer Center in the laboratory of Dr. G. May. Many of the nonaccessioned stocks are stored as silica gel and freezer stocks for simplicity.

B. Molecular Genetic Materials

Cloned genes, cosmids, and BACs are stored at −80°C either in 2-ml screw-cap vials or in multiwell plates. Duplicate sets of each gene library are maintained in separate freezers. For cloned genes, DNA samples are maintained at −20°C. Because they are widely distributed, the gene libraries are not specifically duplicated, nor are the cloned genes.

VIII. Use of the Collection

The FGSC serves a steady demand and in 2001 fulfilled 387 orders. Of these, 185 were to foreign addresses and 202 were to U.S. addresses. Although the bulk of orders are to the United States, Asia, or Western Europe, materials were sent to 40 countries in 2001 (Fig. 3). The 387 orders in 2001 comprised 1081 fungal strains, 240 cloned genes, and 94 gene libraries. The FGSC presently distributes on average 110–115 cultures per month. This is similar to what it has distributed in the past and over the past 5 years (1997–2001) the FGSC distributed 6389 cultures and 452 gene libraries. In the entire history of the FGSC, over 55,000 cultures have been distributed.

IX. FGSC Clientele

The majority of the FGSC clients are researchers at academic institutions (Table II). This is reflected in the numbers of cultures that are distributed as well as the numbers of individuals on the FGSC mailing list. The number of researchers at U.S. institutions is roughly equal to the number at institutions outside the United States. Although the original focus of the FGSC was to serve the *Neurospora* and *Aspergillus* research communities, there are now researchers from a variety of fields among the FGSC constituency. The advent of molecular genetics has allowed many plant pathologists to use techniques and materials

FIG. 3. Destinations of strains from the FGSC in 2001.

developed with *Neurospora* and *Aspergillus* to conduct studies otherwise impossible. Other areas that have developed recently include medical mycology, industrial mycology, and applied chemistry.

X. FGSC Support

Although the FGSC has been supported by the National Science Foundation Division of Biological Infrastructure, Research Resources Cluster in the Support of Living Stock Collections program, it depends to a great extent on user fees to support its daily activities. Laboratory supplies, shipping, and printing are all supported by user fees. In the past year, the FGSC has switched from the U.S. Postal Service to a commercial courier (UPS) for most of our shipments. There are several reasons for this, but it has necessitated that a specific shipping fee be passed on to users. Notwithstanding the need to generate fees, the FGSC has a long tradition of providing materials to researchers without regard to their ability to pay. Moreover, the FGSC has a fee cap for fungal strains designed to allow new researchers to obtain the materials that they need without imposing onerous fees. The fee cap does not

TABLE II

NUMBERS OF STRAINS SENT TO DIFFERENT ORGANIZATIONS

	1997	1998	1999	2000	2001
U.S. academic	576	431	418	421	316
Foreign academic	519	593	339	306	273
U.S. company	55	136	52	41	14
Foreign company	20	28	13	11	7
U.S. governmental	9	5	0	0	0
Teaching	18	41	46	66	64
Internal use	3			55	0

apply to for-profit organizations or to molecular resources, although the FGSC does try to accommodate people's needs. Although recognizing the needs of academic laboratories, the FGSC has asked a substantially larger fee from commercial laboratories. This practice is typical among culture collections. The FGSC fee list is published in the FGSC catalog and online at the FGSC website.

XI. FGSC Website

In 1993 the FGSC established a site on the developing Internet. At first only strain lists and meeting abstracts were available on a gopher site, but this soon grew into an interactive site with various searches as well as listings of strains, clones, gene libraries, and meeting information. After going through a series of temporary site locations, the FGSC site is permanently located at http://www.fgsc.net where the FGSC hosts a bulletin board, online abstract submission for the Fungal Genetics Conferences, various interactive searches, back issues of the FGN, methods and protocols, and material for teaching with fungi. In the past few years, the FGSC site has garnered over 5,00,000 hits per year. The number of resources utilized is very high and follows academic year patterns. For example, the Fungal Genetics Conference material is most actively used in the weeks of online registration and in the weeks preceding the meeting.

As the FGSC database has developed, and as the *Neurospora* genome has become available, the FGSC has worked with the WICGR to provide links from our database to the *Neurospora* genome server and links to our database from WICGR. This is in addition to providing links to identified genes in Genbank, where appropriate. The FGSC is working with website developers and scientists to provide more

media content, micrographs, culture images, and video of cells, and micromanipulation of hyphae.

XII. Recordkeeping

Records of each strain were originally kept exclusively on paper FGSC deposit sheets in three-ring binders. This allowed for a variety of information to be maintained about each strain, including when it was received and preserved, what its requirements were, to whom it was sent, its genotype, and other relevant information. However, this did not allow the identification of strains by particular characteristics. To facilitate this, Mr. C. Wilson created an electronic database, using the database program dBase, for the FGSC. In keeping with developments in electronic and information technology, the FGSC updated to an interactive, relational database in Microsoft Access in 1998 (McCluskey, 2000a). This has enabled the strain database to be searched online and provides unprecedented access to the information to the FGSC clientele. The database also allows easy identification of strains with any combination of characteristics.

XIII. Publications

A. *Fungal Genetics Newsletter*

The FGSC publishes the *Fungal Genetics Newsletter* (FGN, originally *Neurospora Newsletter*) in cooperation with the editorial board of the FGN. The FGN is peer-reviewed and is published once per year. The FGSC distributes the FGN in print format and online. Being online since 1993 makes the FGN a pioneering journal. Originally published as part of the *Neurospora* Newsletter and later in the *Fungal Genetics Newsletter*, the FGSC catalog has grown to be too big for inclusion in the FGN. Although the FGSC catalog has information not found elsewhere, the number of people who request print catalogs is dropping precipitously. There are several reasons for this, the main being the ease of finding materials on the FGSC website. Moreover, the FGSC catalog is now available online at the FGSC website.

B. Program for the Fungal Genetics Conference at Asilomar

The FGSC has acted as a repository of information in a number of ways, including the organization, preparation, and publication of program books for the biannual Fungal Genetics Conference (FGC) and the

newly reestablished biannual *Neurospora* meeting. The FGC grew out of the *Neurospora* Information Conference and eventually became the primary meeting for fungal genetics. In years past, the FGSC has worked with the organizers of the European Congress on Fungal Genetics to host the meeting abstracts at the FGSC website. The FGSC has served as a means of disseminating information throughout its existence. We have maintained an extensive reprint collection, originally established by E. L. Tatum, and currently have over 5200 articles, dissertations, and chapters in our collection. This has helped the FGSC in providing information on the use of strains in the collection.

XIV. Future Directions

The FGSC will continue to hold and distribute the fungal strains, including the mutants and wild-type strains that make up the bulk of the collection, and will strive to add new materials as they develop. The rate of accession of new strains and related materials has been steady, with the exceptions of the large collections (Table III). It is expected that as established researchers retire, the FGSC will expand to hold a variety of new species. Already, the FGSC is expecting to receive a selection of *Schizophyllum commune* strains from the collection of Dr. C. Raper at the University of Vermont. The FGSC has also agreed to hold knockout strains of *M. grisea* and *N. crassa* as they are developed and expects to receive thousands of such mutants from the systematic knockout efforts planned, proposed, and in progress. Working with the fungal genome sequencing effort at the WICGR, the FGSC holds cosmid and BAC libraries used for *N. crassa* and has received commitments for the deposit of similar materials for *M. grisea*. A further extension of the

TABLE III

Recent Material Acquisition

Category	1997	1998	1999	2000	2001
Aspergillus	40	23	4	1154	33
Neurospora	42	11	3940	31	59
M. grisea	–	–	–	–	132
Other	5	4	18	3	0
Plasmids	33	18	11	5	4
Libraries	2	7	2	0	6
Totals	122	63	3975	1193	234

Whitehead effort will see the FGSC beginning to hold additional fungi and molecular resources relevant to the sequencing of these fungi. Early candidates likely include *Cryptococcus neoformans*, *Rhizopus arrhizus*, *Coprinus cinereus*, and *Ustilago maydis*. Although there is a risk of diluting the focus of the FGSC, the opportunity to expand our service to new and developing research communities is one that cannot be passed up. Moreover, much as the FGSC has expanded its mandate in the past, this will allow the FGSC to support research in a variety of fungal genetic systems.

XV. Summary

The FGSC, which began as a specialized repository for *Neurospora* and *Aspergillus* mutants, has grown to hold over 16,000 fungal strains as well as a variety of molecular genetics tools. The FGSC has expanded to include a variety of different fungi including *Magnaporthe* and *Fusarium* and is part of the *Magnaporthe* genome and knockout projects. The FGSC serves as a central clearing house for information in fungal genetics and has a role in facilitating the meetings of the *Neurospora* and fungal genetics communities. The FGSC is a model for the development of a culture collection much as *Neurospora* serves as a model organism.

Acknowledgments

The author would like to acknowledge the assistance of Dr. J. Kinsey, Dr. S. Pichoff, S. Garcia, N. Palenske, and A. Daggett McCluskey for their thoughtful reviews of the manuscript.

References

Barratt, R. W. (1986). Stocks from Tatum *Neurospora* Collection. *Fungal Genet. Newslett.* **33,** 49–58.

Brunelli, J. P., and Pall, M. (1993). A series of yeast/*Escherichia coli* lambda expression vectors designed for directional cloning of cDNAs and cre/lox-mediated plasmid excision. *Yeast* **9,** 1309–1318.

Davis, R. H. (2000). "*Neurospora*. Contributions of a Model Organism." Oxford University Press, Oxford.

Ebbole, D. E. (1990). Vectors for construction of translational fusions to β-galactosidase. *Fungal Genet. Newslett.* **37,** 15–16.

Exley, G. E., Colandene, J. D., and Garrett, R. H. (1993). Molecular cloning, characterization, and nucleotide sequence of *nit-6*, the structural gene for nitrite reductase in *Neurospora crassa*. *J. Bacteriol.* **175,** 2379–2392.

Hamer, L., and Gilger, S. (1997). Bacterial transposons containing markers for fungal gene disruption. *Fungal Genet. Newslett.* **44,** 19–23.

Harris, S. D., Morrell, J. L., and Hamer, J. E. (1994). Identification and characterization of *Aspergillus nidulans* mutants defective in cytokinesis. *Genetics* **136,** 517–532.

Jacobson, D. J., Barton, M. M., Dettman, J. R., Hiltz, M. D., Powell, A. J., Saenz, G. S., Taylor, J. W., Glass, N. L., and Natvig, D. O. (2001). *Neurospora* in western North America: A model system in the backyard. *Fungal Genet. Newslett.* **48** (Suppl.), 62.

Jong, C. S., and Birmingham, J. M. , (1992.) Culture collections: Sources and management of *Aspergillus* cultures for biotechnology. *In "Aspergillus,* Biology and Industrial Applications" (J. W. Bennett and M. A. Klich, Eds.), Butterworth-Heinemann, Boston. pp. 313–326.

Jong, S. C., and Davis, E. E. (1976). Reproducibility of vitamin assays with mutants of *Neurospora crassa* maintained by freeze-drying. *Can. J. Microbiol.* **22,** 1062–1064.

Kupfer, D. M. (1999). Development, analysis and use of an expressed sequence tag database from the multicellular ascomycete, *Aspergillus nidulans.* Ph.D. Dissertation, University of Oklahoma, Oklahoma City.

McCluskey, K. (2000a). A relational database for the FGSC. *Fungal Genet. Newslett.* **47,** 74–78.

McCluskey, K. (2000b). Long term viability of *Neurospora crassa* at the FGSC. *Fungal Genet. Newslett.* **47,** 110.

Nelson, M. A., Kang, S., Braun, E. L., Crawford, M. E., Dolan, P. L., Leonard, P. M., Mitchell, J., Armijo, A. M., Bean, L., Blueyes, E., Cushing, T., Errett, A., Fleharty, M., Gorman, M., Judson, K., Miller, R., Ortega, J., Pavlova, I., Perea, J., Todisco, S., Trujillo, R., Valentine, J., Wells, A., Werner-Washburne, M., Yazzie, S., and Natvig, D. O. (1997). Expressed sequences from conidial, mycelial and sexual stages of *Neurospora crassa. Fungal Genet. Biol.* **21,** 348–363.

Olson, L. W. (1984). Allomyces—a different fungus. *Opera Botanica* **73,** 1–96.

Orbach, M. J., Sachs, M. S., and Yanofsky, C. (1990). The *Neurospora crassa arg-2* locus. Structure and expression of the gene encoding the small subunit of arginine-specific carbamoyl phosphate synthetase. *J. Biol Chem.* **265,** 10981–10987.

Osherov, N., Mathew, J., and May, G. S. (2000). Polarity-defective mutants of *Aspergillus nidulans. Fungal Genet. Biol.* **31,** 181–188.

Perkins, D. D. (1997). Chromosome rearrangements in *Neurospora* and other filamentous fungi. *Adv. Genet.* **36,** 239–398.

Perkins, D. D., and Davis, R. H. (2000). *Neurospora* at the millennium. *Fungal Genet. Biol.* **31,** 153–167.

Perkins, D. D., Radford, A., and Sachs, M. S. (2001). "The *Neurospora* Compendium. Chromosomal Loci." Academic Press, San Diego.

Prade, R. A. (2000). The reliability of the *Aspergillus nidulans* physical map. *Fungal Genet. Biol.* **29,** 175–185.

Prade, R. A., Griffith, J., Kochut, K., Arnold, J., and Timberlake, W. E. (1997). In vitro reconstruction of the *Aspergillus* (= *Emericella*) *nidulans* genome. *Proc. Natl. Acad. Sci. USA* **94,** 14564–14569.

Sweigard, J. A., Chumley, F., Carroll, A., Farrall, L., and Valent, B. (1997). A series of vectors for fungal transformation. *Fungal Genet. Newslett.* **44,** 52–53.

Turner, B., Perkins, D. D., and Fairfield, A. (2001). *Neurospora* from natural populations: A global study. *Fungal Genet. Biol.* **32,** 7–92.

Wilson, C. (1986). FGSC culture preservation methods. *Fungal Genet. Newslett.* **33,** 47.

Xu, J. R., and Leslie, J. R. (1996). A genetic map of *Gibberella fujikuroi* mating population A (*Fusarium moniliforme*). *Genetics* **143,** 175–189.

Zhu, H., Nowrousian, M., Kupfer, D., Colot, H. V., Berrocal-Tito, G., Lai, H., Bell-Pedersen, D., Roe, B. A., Loros, J. J., and Dunlap, J. C. (2001). Analysis of expressed sequence tags from two starvation, time-of-day-specific libraries of reveals novel clock-controlled gene. *Genetics* **157,** 1057–1065.