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Fungus Culture Collections as a Biotechnological Resource

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Introduction

Fungi were deliberately cultured experimentally on plant materials in 1718 by Micheli (1729), but yeasts and filamentous fungi of value in the production of fermented foods and drinks have been maintained as 'starters' for at least 3000 years. However, it was not until the mid-nineteenth century that sterile techniques started to be developed; solid media were first introduced for fungi by Vittadini (1852). Concerted efforts then started to be made to preserve isolates in the living state so that they could be used for experiments and also in teaching (Ainsworth, 1976). Cultures of fungi were made commercially available by Kral from the German Technical University in Prague in the late nineteenth century, but the first independent centre to endeavour to preserve and supply a wide range of fungus cultures was the Centraalbureau voor Schimmelcultures (Baarn, The Netherlands; CBS), established in 1904 (von Arx and Schipper, 1978; de Hoog, 1979). Apart from their value in teaching and pure research, the main areas of activity originally serviced by most fungal collections were brewing, agriculture and medicine. The importance of such collections was extended dramatically in the 1930s following the discovery of penicillin, and the pharmaceutical industry continues to find that fungi are a rich source of biologically active novel

Abbreviations: CAB, Commonwealth Agricultural Bureaux; CMI, Commonwealth Mycological Institute; CODATA, Committee on Data for Science and Technology; ECCCO, European Culture Collection Curators' Organization; ICME, International Centre for Microbial Engineering; ICRO, International Cell Research Organization; IDA, International Depositary Authority; IUBS, International Union of Biological Sciences; IUMS, International Union of Microbiological Societies; JFCC, Japanese Federation for Culture Collections; MIRCENS, Microbiological Resource Centres; NATLAS, (UK) National Testing Laboratories Accreditation Scheme; UKFCC, United Kingdom Federation for Culture Collections; UNEP, United Nations Educational Program; UNESCO, United Nations Educational, Scientific and Cultural Organization; USFCC, United States Federation for Culture Collections; WDC, World Data Center; WFCC, World Federation of Culture Collections; WHO, World Health Organization.

NB: Acronyms of individual Culture Collections are listed in Appendix A, pages 442–453.

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compounds. In the 1980s a further spectacular phase of growth in the demand for collections of fungus cultures is being witnessed as a direct result of increased interest in biotechnological processes (Smith, 1981; Berry, 1983; Smith, Berry and Kristiansen, 1981, 1983); they are recognized as being a major microbiological resource (Kirsop, 1983). The known biotechnological applications of fungi are summarized in *Table 1*

The objective of this present contribution is both to describe the resources available to biotechnology and related fields through Culture Collections maintaining fungi, and to identify ways in which the resource might be developed to increase both its value to the industry and the accessibility of the data. While this review is concerned only with fungi, many of the points discussed apply also to other groups of micro-organisms preserved in Culture Collections.

Organization

INTERNATIONAL

All Culture Collections are represented at the international level by the World Federation of Culture Collections (WFCC) (which was founded in Paris in 1966 under the auspices of UNESCO). The WFCC is accepted by both the International Union of Microbiological Societies (IUMS) and the International Union of Biological Sciences (IUBS) and provides a forum for discussion of all matters relating to Culture Collections. Conferences are held every four years, the most recent being in Bangkok in November 1984 with the theme 'International Resources for Biotechnology'. The proceedings of these meetings are published (Iizuka and Hasegawa, 1970; Pestana de Castro *et al.*, 1976; Fernandes and Pereira, 1977; Kocur and Da Silva, 1984). Membership of the WFCC is open to any Culture Collection. The WFCC publishes a *Newsletter*, but is not directly concerned with cataloguing the resource; that task is the province of the World Data Center, considered further below (page 426).

A major initiative to facilitate collaboration between collections was taken by a working group of the UNEP/UNESCO/ICRO Panel on Microbiology in 1974 which established the concept of a World Network of Microbiological Resource Centres (MIRCENS) with objectives which included providing the infrastructure for a world network, strengthening efforts in conservation, the promotion of the applications of microbiology, and providing focal centres for the training of manpower (Da Silva, Burgers and Olembo, 1977). Fifteen MIRCENS have been recognized, of which eight are concerned wholly or partly with biotechnological aspects of mycology (*see* Da Silva, 1984) and are becoming particularly important in fostering the development of expertise. Two MIRCENS are based on fungal culture collections: those of the Commonwealth Mycological Institute (CMI) at Kew (UK) and the International Centre for Microbial Engineering (ICME) at Osaka (Japan).

In Europe, the European Culture Collection Curators' Organization (ECCCO), established in 1982, provides a forum similar to the WFCC.

Table 1. A synopsis of the known industrial and biotechnological applications of fungi (including yeasts)

Applications	Examples of genera	Sources of further information
Brewing and wine making	*Saccharomyces*	Reed, 1982; Steinkraus, 1983
Baking doughs (breads)	*Saccharomyces*	Reed, 1982
Fermented foods	*Monascus, Neurospora, Rhizopus, Penicillium*	Hesseltine, 1965; Reed, 1982; Steinkraus, 1983
Cheeses	*Penicillium*	Onions, Allsopp and Eggins, 1981
Organic acid production (e.g. citric and oxalic acids)	*Aspergillus, Penicillium*	Onions, Allsopp and Eggins, 1981
Vitamins (e.g. riboflavin)	*Aspergillus, Blakeslea, Nematospora*	Onions, Allsopp and Eggins, 1981
Enzyme production	*Aspergillus, Trichoderma*	Smith, Berry and Kristiansen, 1983
Antibiotics (e.g. penicillins, cephalosporins)	*Acremonium, Penicillium*	Korzybski, Kowzyk and Kurylowicz, 1979
Mycoherbicides	*Colletotrichum*	Templeton, TeBeest and Smith, 1979
Pesticides and insecticides	*Beauveria, Trichoderma, Verticillium*	Brady, 1981; Smith, Berry and Kristiansen, 1983
Food (human and animal), direct usage/biomass	Macrofungi, especially *Agaricus, Lentinus, Pleurotus, Volvariella*	Chang and Hayes, 1978
Single-cell protein (SCP)	*Fusarium*	Birch, Parker and Worgan, 1976
SCP from waste	*Chaetomium, Fusarium, Paecilomyces, Trichoderma*	Birch, Parker and Worgan, 1976; Smith, 1981
Waste degradation	*Chaetomium, Endomycopsis, Trichoderma*	Birch, Parker and Worgan, 1976
Genetic engineering	*Aspergillus, Penicillium*	Smith, Berry and Kristiansen, 1981
Mycorrhizal strains	*Boletus, Rhizoctonia, Russula*	Harley and Smith, 1983

The only Culture Collection of fungi with an international legal status appears to be that of the Commonwealth Mycological Institute (CMI; Hawksworth, 1985). Based in the UK (and incorporating the UK National Collection of Fungus Cultures), this Collection is supported by the 29 member Governments of the Commonwealth Agricultural Bureaux (CAB).

NATIONAL

In the UK, all Collections and individual users can join the UK Federation for Culture Collections (UKFCC); this was founded in 1975. Comparable organizations are established in many other countries, notably Japan (JFCC) and the USA (USFCC).

Particular publicly funded Collections are recognized as of national status in some countries; these are usually directly supported by Government funds and located either at Government research institutes or at independent locations. In most countries these are supplemented or replaced by a more informal series of Collections associated with individual scientists, research stations, universities or industrial laboratories. Such collections generally hold only groups of organisms directly pertinent to their work and many do not supply cultures or provide other services pertinent to biotechnology.

The total number of Culture Collections in the world including fungi is unknown. At least 200 of the 566 collections contributing records to the World Data Center hold some strains of fungi (McGowan and Skerman, 1982), but this list is far from exhaustive as numerous smaller collections maintained for private use and housed by university departments, research institutes and industry are omitted. Some collections are not able to make their holdings known or to supply cultures for either commercial or research reasons, or (because of their limited resources) to process requests.

Key features of 73 Culture Collections including fungi are compiled in *Appendix A*, constructed on the basis of questionnaires sent out in connection with the preparation of this review. The information provided therein can be supplemented by that compiled for the International Mycological Congress (1971) and by Onions (1978), McGowan and Skerman (1982), and the European Culture Collection Curators' Organization (1984). Further, in response to the demands of biotechnology, many countries are currently actively establishing or developing national Culture Collections. The information presented in *Appendix A* is consequently not to be treated as definitive.

Resources and services

This section describes the types of resources and range of services that are available from Collections, but the extent to which individual fungal Culture Collections are able to supply these varies markedly. Some indication of the most appropriate Collections to approach with reference to a particular enquiry or request may be obtained from a study of *Appendix A*. No single collection provides all the services indicated here for all groups of fungi at this time.

CONSERVATION

The number of different isolates of fungi currently maintained in the living state throughout the world's Collections is in excess of 170 000 (*see Appendix A*), representing approximately 7000 species. This latter figure amounts to

11% of the 64200 accepted species of fungi (Hawksworth, Sutton and Ainsworth, 1983), but it must be remembered that the actual number of species in the world has been estimated by several authors as in excess of 250000. Over 1500 new species of fungi are currently being described annually (catalogued in the *Index of Fungi*).

To maintain even a fully representative range of isolates from such a large number of organisms is a daunting task beyond the scope of all but the largest Collections, but even these are then not often able to build up large holdings of strains of single species, genera or other small groups. Adequate curation requires specialist back-up from biochemists, geneticists or taxonomists (*see* page 429); in addition, the best methods of preservation vary from group to group (Smith and Onions, 1983; Kirsop and Snell, 1984). In practice, the extent to which individual strains are duplicated in the various Collections is not as great as might be assumed. Precise figures are not available but a superficial survey of catalogues of holdings suggests that replicates rarely amount to more than about one-quarter of the isolates retained in a Collection. For this reason, and also because of the different specializations or emphases of Collections, the various Collections are most appropriately regarded as parts of a collective resource. It would be incorrect to consider the smaller Collections as merely subsets of what is already held in the larger Collections and consequently of only minor importance.

The strains collectively maintained between the fungal Culture Collections provide a tremendous genetic resource, including not only isolates of known importance to biotechnology and other aspects of applied biology, but a source of supply of isolates which may later prove to be of immense significance. In cases where particular properties in a fungus are being sought, the most cost-effective method of searching may often be to screen a wide variety of isolates already maintained in Culture Collections. In this way, isolates from a broad spectrum of taxonomic groups, regions of the world, and substrata can be tested without the need to mount expensive collecting trips. Further, many fungi are extremely rarely collected or isolated: indeed, a not inconsiderable number of species have been isolated from nature on only a single occasion; these are most unlikely to be refound in nature but are often available from at least one Collection.

The extent and value of the unique conserved genetic resource is impossible to quantify. However, in view of the broad taxonomic spectrum of organisms, the large number of species and the substantial information already available on, for example, the secondary metabolites (Turner, 1971; Turner and Aldridge, 1983) it must be regarded as massive even by comparison with the bacteria and vascular plants. In most cases the biological activities of fungal products remain to be assessed: their potential therefore cannot be estimated in any authoritative way. Nevertheless, the conservation of this resource should be the primary objective of fungus Culture Collections. It constitutes a fundamental resource for numerous areas of pure and applied biology.

Living cultures of fungi (including yeasts) are not yet acceptable as nomenclatural types in the same way as bacteria, although some progress is

being made in this direction (Hawksworth, 1984). Nevertheless, dried cultures permanently preserved in herbaria are acceptable, and living cultures of these strains (usually referred to as 'ex-type') are of immense value in the fixing of the application of names of fungi and yeasts whose distinguishing characters are seen easily only in living cultures. In keeping these reference strains, Culture Collections consequently contribute to nomenclatural stability.

As the methods suitable for one group of fungi may not be suitable for another (Smith and Onions, 1983), and some fungi and yeasts may also undergo changes in their physiology, biochemistry or pathogenicity if not carefully preserved (Jong and Davis, 1978; Kirsop, 1980), any collection wishing to maintain a broad spectrum of isolates over long periods must have the equipment, personnel and financial resources to operate a variety of preservation methods in parallel (*Table 2*). Methods currently in use for the preservation of fungi include frequent transfer (*Figure 1a*), storage in domestic refrigerators and deep-freezers (*Figure 1b*), storage under mineral oil (*Figure 2*), in soil, in water or in silica gel, freeze drying (lyophilization) (*Figure 2*) and storage in liquid nitrogen (vapour phase and (or) liquid phase; (*Figure 3*). In some cases research projects have to be carried out to

Table 2. A comparison of the main preservation methods in use for fungi (including yeasts). Adapted in part from Smith and Onions (1983).

Preservation method	Cost	Longevity	Genetic stability	Range of fungi
Transfer on slopes				
18–20°C	Low	1–6 months	Variable	Almost all except obligate parasites
4–7°C	Low	6–12 months	Variable	
Mineral oil	Low	1–35 years	Poor	Almost all except obligate parasites
Water	Low	2–5 years	Moderate	Most (essential for some aquatic groups)
Soil	Low	5–20 years	Poor	Most
Silica gel	Low	5–15 years	Good	Most with robust spores (not yeasts)
Lyophilization	High	4–40+ years	Good	Most sporing fungi except Mastigomycotina
Liquid nitrogen	Very high	15 years–infinite(?)	Good	All (including fungi on plant materials)
Deep freeze				
−17 to −23°C	Low	4–5 years	Moderate	Almost all
−50 to −100°C	High	5–10 years	Good	Almost all
−130 to −160°C	High	Unknown	Good	Probably almost all

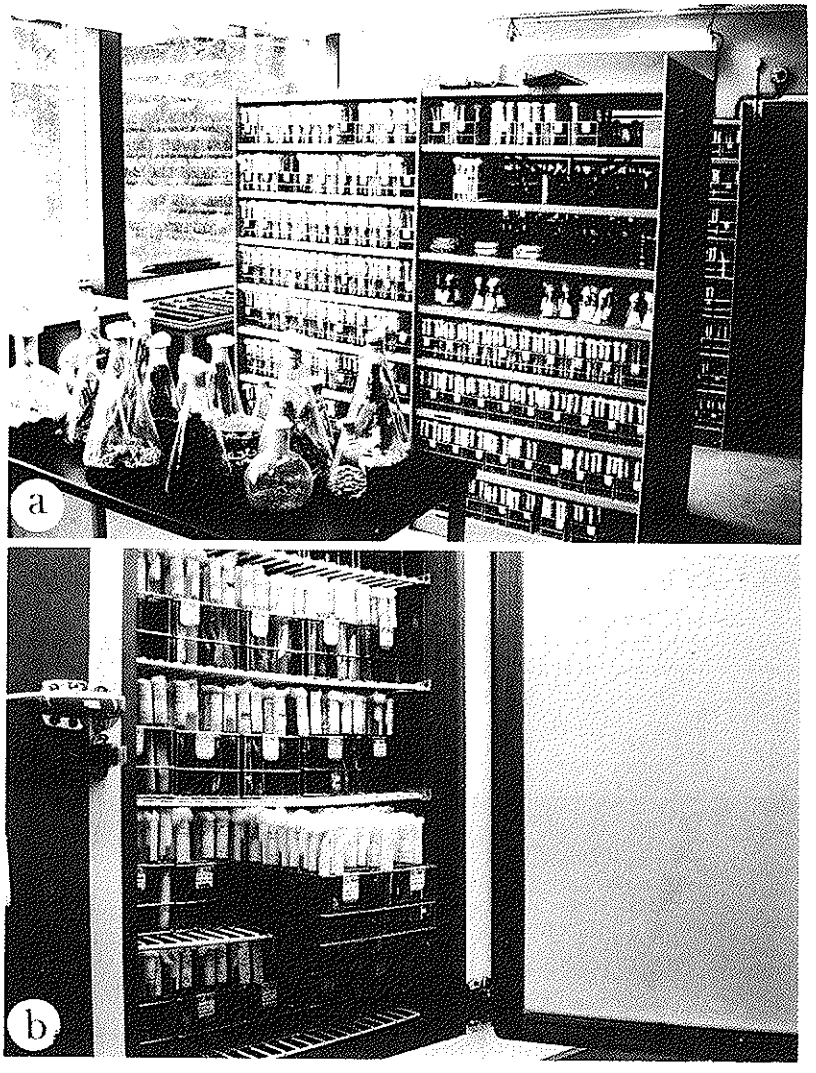


Figure 1. (a) The active Collection maintained by frequent transfer, and (b) part of the Collection kept at −40°C at the Centraalbureau voor Schimmelcultures (CBS).

determine the most satisfactory preservation methods. This is especially so for fungi being maintained for their pathogenic, physiological, biochemical or metabolite-producing properties; in these cases the collection must have the facilities to test for these attributes after preservation.

Certain preservation procedures may be effective over long periods. Many of the strains brought by Went from Java to the CBS (Centraalbureau voor

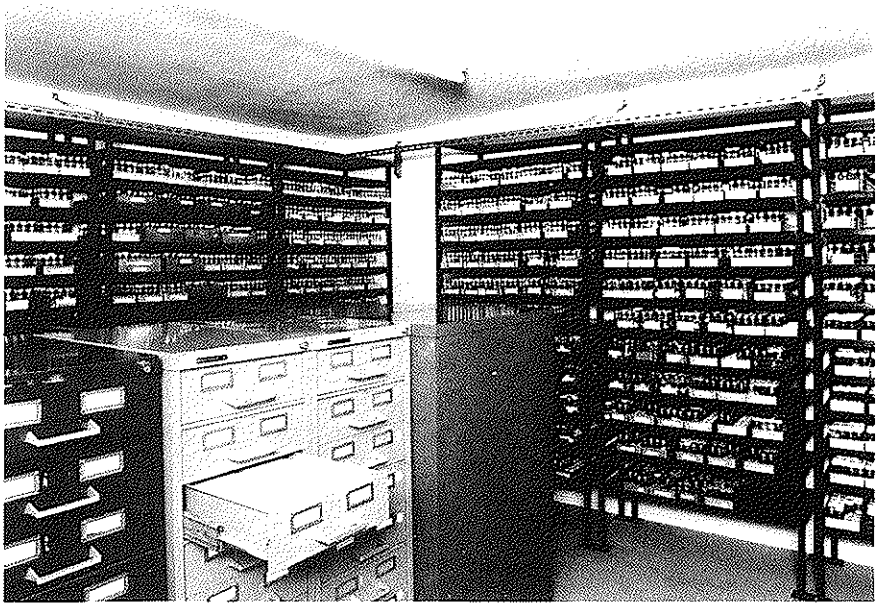


Figure 2. Culture store at the Commonwealth Mycological Institute (CMI). The shelves are filled with isolates preserved under mineral oil and the drawers with lyophilized ampoules. The temperature is maintained at approximately 15°C by an air-conditioning unit.

Figure 3. Liquid nitrogen (vapour phase) preservation containers at the American Type Culture Collection (ATCC).

Schimmelcultures) when he assumed responsibility for it in 1904 are still viable. Lyophilization, however, has been found at the American Type Culture Collection (ATCC) to decrease in effectiveness after 30 years (Jong, Levy and Stevenson, 1984); it has not been in service as long in other major fungal collections but comparable results may be expected (Schipper and Bekker-Holtman, 1976; Smith and Onions, 1983). The most satisfactory broad-spectrum long-term storage technique now in use is undoubtedly storage above or in liquid nitrogen at −196°C (liquid phase), which may give almost infinite preservation. Mechanical deep-freezers with temperatures down to about −150°C are just becoming available and may become increasingly valuable. Most major collections endeavour to preserve important isolates by at least two separate methods, often also with back-up tubes or ampoules housed in a different building for additional security.

Although there are strains that are sensitive to the lyophilization technique (Smith and Onions, 1983; Kirsop and Snell, 1984), most of these can be stored in or above liquid nitrogen. Because of the vulnerability of supply of liquid nitrogen the use of mechanical freezers to hold suitable ultra-low temperatures is being examined (Onions and Smith, 1984). The two techniques of lyophilization and liquid nitrogen storage have been used to retain particular properties. The pathogenicity of sensitive obligate pathogens has been retained by liquid nitrogen storage (O'Brien and Webb, 1958; Gale, Schmitt and Bromfield, 1975), as have the albino and brown phenotypes of *Histoplasma capsulatum* (Butterfield and Jong, 1975) and the slime mutants of *Neurospora crassa* (Jong and Davis, 1979). Vitamin-requiring mutants of *Neurospora crassa* can be kept stable by lyophilization, enabling them to be used for assays (Jong and Davis, 1976). Collections are considering the problem of maintaining strains whose characteristics depend on the presence of plasmids, for example the pathogenicity of certain fungi (Hashiba *et al.*, 1984). Little information is available on the preservation of plasmid-containing fungi and this is an area urgently requiring further research. In some cases the reported properties of strains of fungi may be due to the presence of plasmids.

Research projects often extend over a period of years. Laboratories without adequate culture-preservation facilities consequently run the risk of strains being lost during the course of research programmes. If isolates undergoing investigation are deposited in a Culture Collection, not only will they be re-available if laboratory cultures become contaminated or die, but also they can be cited in resultant publications and supplied to others wishing to confirm or develop work on the same strains. Some major Collections are willing to retain, in confidence, isolates which are being evaluated in other laboratories, as a 'safe-deposit' service for a modest fee; such strains consequently are not cited in catalogues.

Security is also important where pathogens are being maintained. Stringent laboratory safety practices are required for conserving pathogens harmful to man (*see* Collins, 1984), while quarantine regulations must be complied with for fungi causing plant diseases. Regulatory authorities are usually reluctant to license more than a few centres for the retention of a wide range of

potentially harmful isolates in a country, licences often being otherwise required to maintain and work on individual species outside those centres. In general, only collections with special facilities for handling medically important fungi are able to maintain the strains pathogenic to man and animals. Those wishing to work with such fungi are recommended to approach their main national collection for advice in the first instance.

SUPPLY OF STRAINS

The major service fungal Culture Collections all supply strains for research, teaching and industry. Differential rates of charging are generally applied, but most collections will accept fresh isolates of interest to their collection in exchange for ones they have available for distribution.

Owing to the historical background of most Culture Collections, there is often a high degree of financial subsidy provided by large academic, trade or governmental agencies. This usually results in cultures being sold at well below their true economic cost.

In the case of pathogenic strains, which are classified according to the degree of hazards in the case of organisms harmful to man (Kurtzman, 1984), licences may be needed before particular isolates can be supplied to a laboratory. Plant disease quarantine regulations vary in different countries but can limit shipments of fungi and require licences to work with them (Johnston and Booth, 1983).

INFORMATION

The extent to which collections are able to make available information on their holdings varies markedly. Most of the major collections publish catalogues (*see Appendix A*), usually at 2- to 3-year intervals (sometimes with supplements between) which may be supplied either free of charge or offered for sale. Many of the smaller collections do not publish independent catalogues but some indication of the species held can often be obtained from the *World Directory of Collections of Cultures of Microorganisms* (McGowan and Skerman, 1982), to which numerous small collections contribute data; 566 collections now provide data for this, of which about 200 maintain at least some fungi (or yeasts). This publication, the first edition of which appeared in 1972, is prepared by the World Data Center (WDC), a MIRCEN currently based at the University of Queensland, which has received financial support from international agencies including UNESCO, UNEP and WHO. Further information on the history and services of the WDC are provided by Skerman (1976, 1984).

The larger Culture Collections are now endeavouring to make the information on the strains held as comprehensive as possible, citing growth requirements, biochemical activities, metabolic products, temperature and pH

optima, etc., plus, in the case of the American Type Culture Collection (ATCC) catalogues, literature references to papers using particular strains. The ATCC data management system is described in detail by Jong (1984). These data are currently largely maintained on in-house micro- or mini-computer systems which can be searched to identify strains with particular combinations of attributes. This possibility is of major interest to biotechnologists and genetic engineers and has led to proposals to establish biotechnological strain databases accessible on-line by industry. For example, a national Biotechnology Database (MiCIS) is being actively developed in the UK by the Laboratory of the Government Chemist (Department of Trade and Industry) and possibilities of an International Microbial Strain Data Network are being investigated by the Committee on Data for Science and Technology (CODATA) and IUMS. It would also be technically feasible to extend the information content of the *World Directory* and to make its data accessible world-wide on-line if it could be linked into a major scientific database such as that provided by CAB (Metcalfe, 1979, 1984).

In addition to repeating information provided when strains were deposited, Culture Collections are uniquely placed to build up data on the strains themselves. A certain amount of information on optimal growth conditions may be derived in the course of preservation procedures, but in addition the potential exists to examine isolates held for particular attributes such as growth requirements, enzyme activity, secondary metabolites, and antibiotic activity against selected organisms. Few Collections have the resources to undertake such programmes of building up the data on their collections but this aspect merits particular attention in the future as biotechnologists and genetic engineers will increasingly search for particular activities or products rather than by Latin binomials (i.e. the scientific names).

Culture Collections may also be able to give advice on much broader fronts than their holdings. Those which are located within, or are associated with, centres of excellence for various aspects of mycology can draw on the expertise of associated specialists in recommending genera or species, the isolates of which may be expected to have particular attributes. Curators may also have catalogues of numerous Collections other than their own, or know the strengths of others, so that additional or alternative sources of isolates can be recommended.

Some Collections have built up substantial collections of reprints or bibliographical notes relating to isolates they hold, which may be relevant to potential users. Furthermore, several of the major Collections have on-line access to leading world bibliographic databases (e.g. BIOSIS, MEDLINE, CAB, CHEMICAL ABSTRACTS) which can assist in identifying species with particular biotechnological properties.

The extent to which, and fields in which, Collections are able to supply advisory services, differ according to the types of strains held and associated expertise. No single Collection can be considered authoritative on all biotechnological problems but an indication of the more appropriate to approach for advice on a particular topic may be obtained from *Appendix A*.

IDENTIFICATION

Culture Collections with experienced taxonomists on their staff can provide identification services (often for a fee). In view of the large numbers of fungi (*see* page 421) and the specialisms of collections, the most appropriate Institute to approach may vary depending on the main group of the fungi concerned.

The verification of the scientific names of isolates with which biotechnologists work is crucial before results are published in either scientific articles or patents. The literature is already too full of elegant physiological and biochemical studies on insufficiently or inaccurately identified fungi. Reports of properties or activities in a wrongly named isolate not only may confuse the literature on that species, but also may cause other workers to waste time and resources looking for the same activities in the true (correctly named) isolates that, in fact, belong to another species. New lines of research could even be initiated on the basis of published papers in which material was erroneously identified.

In the rare cases where specialists able to check identifications cannot be found, it would be helpful to make it clear in publications that some doubt might exist over the identify of a particular strain and to ensure that the isolate concerned was preserved in a major Culture Collection so that its name could be checked by future workers.

The name of an organism is the crucial key to communication on any aspect of it and thus always merits critical verification.

The direct comparison of one culture or specimen with another is a critical part of the identification process. It follows that, in order to provide such a service, a Collection requires not only specialist personnel but also a considerable reference material in the form of both living cultures and dried specimens. The two latter can complement one another in the identification process as species hitherto known only on natural substrata are repeatedly being discovered in culture for the first time. In addition, the nomenclatural types of fungi (including yeasts) must still be dried specimens (*see* Hawksworth, 1984). The herbarium at the Commonwealth Mycological Institute is particularly extensive, consisting of about 300 000 dried reference specimens and dried cultures of microfungi. The most effective identification services are consequently to be found where Collections are located in, or close to, centres of excellence with skilled personnel and substantial library facilities as well as large reference herbaria.

Taxonomies are continuously being improved as more isolates of species become available for comparative studies, and as fresh data on their characteristics is obtained through biochemical, ultrastructural, numerical, or other approaches. As Culture Collections often hold large numbers of isolates of particular genera or species, they are ideal centres from which taxonomists can work to improve the delimitation of species of fungi. Inadequate taxonomies can hamper communication by making it uncertain to what a particular name is being applied; it is important for centres with the collections and expertise necessary to clarify such problems, not to overlook

this need. In the case of many genera of micro-fungi which are proving to be of particular interest in the biotechnological industry (e.g. *Acremonium*, *Aspergillus*, *Chaetomium*, *Fusarium*, *Penicillium*, *Trichoderma*), the taxonomy was totally unprepared for the demands now being placed on it with respect to physiological and biochemical characters; substantial amounts of work to improve the situation are required. Some initiatives in this direction are currently being taken at the Commonwealth Mycological Institute with support from the Biotechnology Directorate of the Science and Engineering Research Council (Onions, Bridge and Paterson, 1984).

Collections themselves also have to be in a position to be able to check continuously the identities of cultures before they are sent out and when transfers are made. If contamination occurs, then a client may be supplied with the wrong organism: wrongly determined or mixed material sent out from Culture Collections has resulted in erroneous reports of activities in the literature. Examples include reports of gliotoxin and viridin production in *Trichoderma viride* when the strain was of *Gliocladium virens* (Webster and Lomas, 1964), of mycotoxin production in the type strain of *Aspergillus parasiticus* which was in fact mixed with *A. flavus* (Kozakiewicz, 1982), and the report that ascospores of *Neocosmospora vasinfecta* and *N. africana* were identical when studied by SEM (van Warmelo, 1976; Cannon and Hawksworth, 1984). If cultures received from a Collection are found to have entirely unexpected properties it is prudent to have their identities confirmed by an appropriate specialist before the publication of results.

In most applications for research funding, a heading rarely found on forms or applications is one for taxonomic services. A greater awareness of services available and more early financial planning would assist researchers and grant-awarding bodies to avoid problems such as those mentioned above.

RESEARCH

In addition to being ideal centres for taxonomic research (*see* page 428) and for research on long-term preservation methods (*see* page 422), major Culture Collections are also ideally placed to undertake other research of primarily biotechnological importance. Potential topics might include:

1. The screening of large numbers of isolates for particular uses and the search for strains with desired properties;
2. Comparative studies of the effectiveness of strains of the same or closely related species in making a particular enzymic conversion or producing particular metabolites;
3. Development and examination of procedures for the detection of particular compounds or activities requiring testing against a large range of fungi;
4. Development and testing of short-term preservation and cultivation methods suitable for use in other laboratories;
5. Studies on the growth requirements of particular groups of species, and
6. Testing types of fermenters for their effectiveness using different groups of fungi.

The curators of most Collections are scientists who are involved to varying degrees in personal research programmes. However, most Collections have insufficient resources and personnel to undertake additional research activities without outside sources of financial support. Their potential contribution to biotechnological research is consequently likely to be realized only through either research awards from appropriate Government bodies or industry, or by undertaking research on specific items on a consultancy basis. In the latter case, users almost invariably require exclusive rights to results which may be held confidentially and never published.

CONSULTANCY

Companies involved in the biotechnology industry working with fungi can be assisted by several of the major fungus Culture Collections on a consultancy basis. In providing advice or services to industry, confidentiality is essential. A company may not even wish it to be known what organisms they are interested in or what properties are being searched for. With the development of biotechnological databases including strain data (*see* page 427), confidential on-line access over normal telephone lines will increasingly become the main way for companies to obtain such information. In the interim, however, Collection staff will be required to draw attention to cultures which might be of interest to a client, using internal strain data included in searchable catalogue files or personal knowledge of isolates. Collections will also generally have copies of the *World Directory* (McGowan and Skerman, 1982) and more detailed individual catalogues available so that they are in a position to identify alternative or additional sources of strains of a particular species.

Consultancy services may also embrace wider aspects of information retrieval, for example from the literature or bibliographic databases (*see* page 427), but contract research and investigative work can sometimes be provided also by the larger service Collections. Contract research could be concerned with any of the fields identified in the preceding section, with the important proviso that the results could not normally be published without the prior approval of the contractor. The most important of these areas in which industry might consider contract research is undoubtedly the screening of wide ranges of isolates for particular attributes. With regard to secondary metabolites, it should be noted that dried cultures preserved for several decades in herbaria may retain these in a detectable form (Paterson and Hawksworth, 1985), so providing a rapid way of screening species that may not be retained in the living state in a particular Collection.

Investigative consultancy work in general mycological biodegradation and biodeterioration is also available from the Commonwealth Mycological Institute, and to a lesser extent from other fungal Culture Collections. Topics in which trouble-shooting services can be provided are wide ranging and include the spoilage of food and manufactured goods, fuel contamination, conservation of library and museum materials, damage to building materials

(including timber), stored agricultural materials (especially seeds) and identification of plant diseases.

Services for the testing of resistance to mould growth are also available from CMI. Cultures in this Collection have been specified for many years for use in testing to British standard specifications but in June 1984 CMI was approved under the UK National Testing Laboratories Accreditation Scheme (NATLAS) so that testing to British and foreign standards can now be undertaken at CMI itself. For general information on mould-growth testing *see* Allsopp and Seal (1985).

PATENTS

Culture Collections also have a key role in patenting procedures where Patents refer to a particular strain of micro-organism. Collections may be approved to act as national or international depositories. The EEC countries have a European Patent Convention 1973 which includes a provision for a list of 'recognized experts' who may be required to advise on matters such as taxonomy, identification, assessment of products, reproducibility of cultivation techniques, etc.; some Collections (e.g. CMI, CBS) have recognized experts on their own staff.

Patenting in a variety of countries can now be facilitated where strains are deposited in Collections recognized as 'International Depositary Authorities' (IDAs) under the Budapest Treaty on the International Recognition of the Deposit of Microorganisms for the Purposes of Patent Procedure. This treaty was first signed in 1977 and ratified by sufficient numbers of signatories to bring it into force in late 1980. In order to be recognized as IDAs, Collections must be able to comply with a complex series of provisions (*see* Kurtzman, 1984), including a guarantee that strains so safeguarded will be maintained for a period of not less than 30 years and must adhere to strict procedures over checks on viability, etc. The cost of depositing patent strains may seem high but they cover the whole 30-year storage period and are modest in comparison with other costs involved in filing patents (Park, 1984). All IDAs are not authorized to cover all micro-organisms and the groups they are approved to handle are specified. The IDAs so far recognized for fungi are listed in *Table 3* in which the groups covered are also indicated.

Valuable practical guidelines on the patenting of micro-organisms are provided by Crespi (1982 and *see also* Chapter 1 of this volume). The legal situation may often be complex and some aspects of the patenting of micro-organisms are currently rather uncertain (Plant, Reimers and Zinder, 1982) or in the process of review (Amatniek, 1983). Professional advice should be sought at an early stage where a strain that might be cited in a patent application is isolated or produced in the laboratory.

TRAINING

Staff of fungus Culture Collections associated with university departments are frequently also involved in teaching at the undergraduate and postgraduate

Table 3. Collections recognized as International Depositary Authorities (IDAs) for fungal strains under Article 7 of the Budapest Treaty

Collection	Status acquired	Fungi that may be deposited†
NRRL Agricultural Research Service Culture Collection*	January 1981	'Progeny of strains of agriculturally important... yeasts, molds...except... Basidiomycetes or other molds that cannot successfully be preserved by lyophilization'
ATCC American Type Culture Collection*	January 1981	'Fungi (including yeasts)' .
FRI Fermentation Research Institute	May 1981	'Fungi, yeasts...except: (a) microorganisms having properties which are or may be dangerous to health or the environment; (b) microorganisms which need the physical containment level P2, P3 or P4...'
CBS Centraalbureau voor Schimmelcultures*	October 1981	'Fungi (including yeasts)'
DSM Deutsche Sammlung von Mikroorganismen*	October 1981	'Fungi, including yeasts,... except any kinds pathogenic to humans or animals. Phytopathogenic kinds are accepted...' [With some exceptions]
NCYC UK National Collection of Yeast Cultures*	January 1982	'Yeasts other than known pathogens that can be preserved without significant change to their properties by freeze-drying or, exceptionally, in active culture'
CMI Commonwealth Mycological Institute*	March 1983	'Fungal isolates, other than yeasts, that can be preserved without significant change to their properties by the methods of preservation in use'
IVI In Vitro International Inc.	November 1983	'Fungi'

*See *Appendix A* for addresses.
†Source: *Industrial Property* 1984, 16–23 (1984).

levels, but some of the larger Collections are able to undertake training of more immediate relevance to biotechnologists working with fungi.

Training in techniques for the handling of fungi and also in culture maintenance procedures suitable to research laboratories are of particular importance. In addition, staff of the longer-established Collections utilizing a range of preservation methods are able to advise staff of Collections in the process of establishment as to the methods most likely to be suitable for the organisms they will handle, bearing in mind the financial and personnel resources they have available. Training in techniques is usually carried out on an individual basis rather than as formally taught courses, because 'hands-on' involvement is desirable. The capacity for Collections to receive trainees is

usually limited so that early applications are normally required; tuition fees are usually charged.

More specialized formal courses provided by CBS and CMI are concerned with the identification of fungi on foods, stored products, materials and agricultural crops. Such studies require the inputs of several expert taxonomists in order to be authoritative; they cannot therefore easily be provided by smaller Collections. Participants are usually drawn from a wide range of countries, and some courses are arranged specifically for students from developing countries through the MIRCEN scheme (*see* page 418).

Intensive one-day seminars for industrialists started to be held at CMI in 1984 when the topics addressed were 'Fungal Toxins' and 'Biotechnology and Fungi'. These involve outside speakers so that highly pertinent 'state of the art' reviews can be presented, enabling participants to obtain a clear authoritative summary of the topic tackled.

Postgraduate training leading to higher degrees can also be arranged at some Collections which are in, or have formal links with, universities that approve them as centres suitable for such training. The range of potential topics for research students is very wide, and may be drawn from any of the main research areas relevant to the interests of collections (*see* pages 428–429). Collection-based research also has a role in the training of personnel who might occupy key positions on the staff of Collections in the future.

Developing the resource

If the potential afforded by the fungal resource maintained in the world's Culture Collections is to be realized in the wide variety of applications already identified (*Table 1*), developments are required in order to strengthen the resource base and to increase the effectiveness with which it can be utilized. This section draws attention to the more important aspects requiring development at this time.

ACQUISITIONS

The value of Culture Collections as a biotechnological resource is dependent on the range of isolates that they are able to supply. Many of the existing fungus collections originated as adjuncts to brewing, pharmaceutical, plant pathological or medical mycology services and their holdings reflect this. There is consequently a need for Collections to develop vigorous acquisitions policies aimed at increasing the numbers of strains of actual or potential biotechnological importance they retain. In view of the large numbers of fungi (page 421) and the wide variety of applications (*Table 1*) it is unrealistic to expect all but the largest Collections to have sufficient resources to develop their holdings across a broad front. Before steps are initiated to increase acquisitions, it is therefore important for Collections to determine their individual priorities. There is a great deal to be gained from a system in which holdings are complementary rather than duplications of strains held elsewhere, as the resource as a whole is then enriched.

When the parameters for the development of acquisitions policies have been formulated, curators will seek to identify potential donors of strains and then proceed to contact them. This will involve both surveys of literature in the appropriate field(s), and personal contacts with workers active in them. Small Collections starting to establish may also find it of value to obtain at least a selection of organisms from the larger service Collections but this could prove expensive and will not increase the resource as a whole.

Depositors of isolates are often permitted a similar number of strains in exchange, free of charge, and free access to their own isolates should they require them in the future.

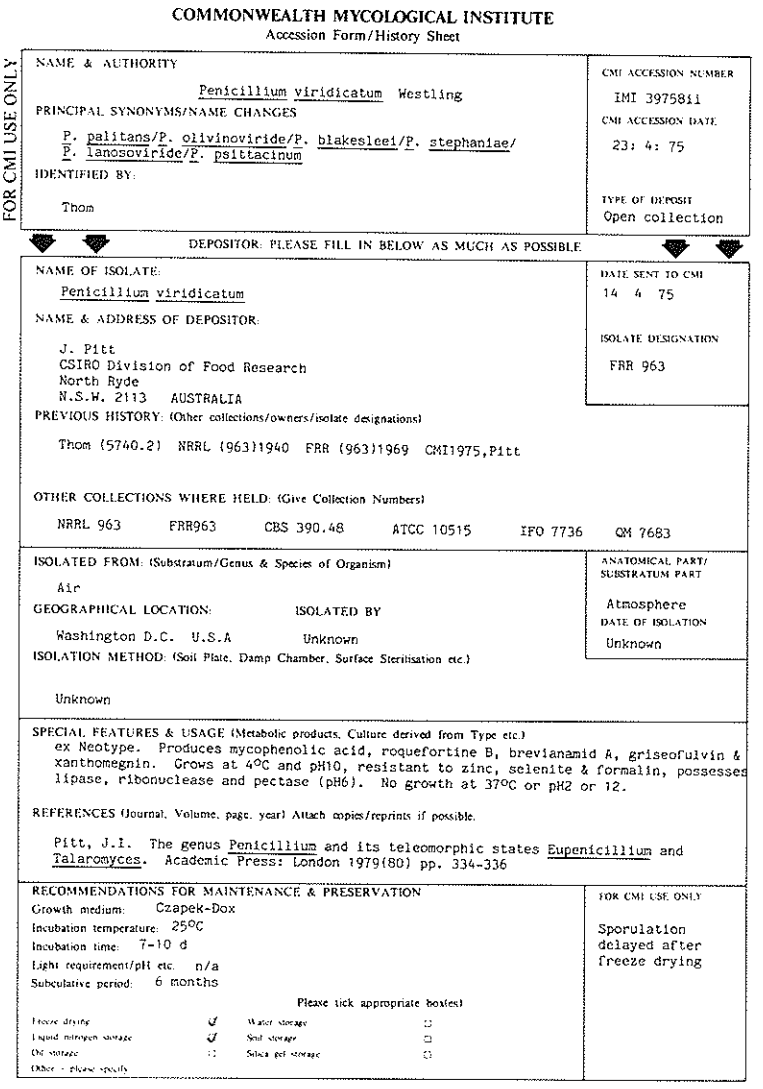
Collections which provide, or are associated with, a world-wide identification service, are assured of a continuous flow of isolates. At CMI, for example, about 6000 cultures and 3000 specimens of fungi are submitted for authoritative determination by specialist taxonomists each year; the more interesting of these are passed to the Culture Collection for preservation as a matter of routine.

Perhaps one of the most important ways of enriching Collections is to encourage research workers routinely to deposit subcultures of those strains on which their publications are based, in at least one major Culture Collection. As pointed out above (page 428), a major problem in fungal biotechnology is the uncertainty which surrounds the identity of strains on which often elegant physiological, biochemical or chemical investigations have been carried out. As a direct result of this, the significance which can be attached to much of the published information is low as the work may not be reproducible. In contrast, if strains are preserved their names can be revised, as may be occasioned by developments in their taxonomy, and the work based on them will continue to be meaningful and of lasting value. The editors and referees of scientific journals can play a useful part in this connection by insisting on depositions of key isolates before the acceptance of papers for publication.

STRAIN DATA

The value of the strains acquired will be increased by the extent of the data which is available on them. Biotechnologists will often be more interested in locating strains with particular properties or products than searching for isolates by their taxonomic name. The extent to which Collections have recorded information on the strains they hold varies considerably. The ATCC have recognized the importance of this for many years (Jong, 1984) and other Collections are now developing this practice to include detailed information on growth conditions and media requirements as well as physiology, biochemistry, chemical products, pathogenicity and known uses (*Figure 4*).

The building-up of data on each strain is an extremely time-consuming, and consequently expensive, task. Nevertheless, the Culture Collections are in a unique position both to extend the data on isolates maintained and to confirm that properties reported when strains were deposited continue to be exhibited. Research work based on isolates held, is a particularly effective way of



COMMONWEALTH MYCOLOGICAL INSTITUTE
Accession Form/History Sheet

FOR CMI USE ONLY

NAME & AUTHORITY
Penicillium viridicatum Westling

PRINCIPAL SYNONYMS/NAME CHANGES
P. palitans/P. olivinoviride/P. blakesleei/P. stephaniae/
P. lanosoviride/P. psittacinum

IDENTIFIED BY:
Thom

CMI ACCESSION NUMBER
IMI 397581i

CMI ACCESSION DATE
23: 4: 75

TYPE OF DEPOSIT
Open collection

DEPOSITOR: PLEASE FILL IN BELOW AS MUCH AS POSSIBLE

NAME OF ISOLATE:
Penicillium viridicatum

NAME & ADDRESS OF DEPOSITOR:
J. Pitt
CSIRO Division of Food Research
North Ryde
N.S.W. 2113 AUSTRALIA

DATE SENT TO CMI
14 4 75

ISOLATE DESIGNATION
FRR 963

PREVIOUS HISTORY: (Other collections/owners/isolate designations)
Thom (5740.2) NRRL (963)1940 FRR (963)1969 CMI1975,Pitt

OTHER COLLECTIONS WHERE HELD: (Give Collection Numbers)
NRRL 963 FRR963 CBS 390.48 ATCC 10515 IFO 7736 QM 7683

ISOLATED FROM: (Substratum/Genus & Species of Organism)
Air

ANATOMICAL PART/ SUBSTRATUM PART
Atmosphere

GEOGRAPHICAL LOCATION: ISOLATED BY
Washington D.C. U.S.A Unknown

DATE OF ISOLATION
Unknown

ISOLATION METHOD: (Soil Plate, Damp Chamber, Surface Sterilisation etc.)
Unknown

SPECIAL FEATURES & USAGE (Metabolic products, Culture derived from Type etc.)
ex Neotype. Produces mycophenolic acid, roquefortine B, brevianamid A, griseofulvin & xanthomegnin. Grows at 40C and pH10, resistant to zinc, selenite & formalin, possesses lipase, ribonuclease and pectase (pH6). No growth at 37°C or pH2 or 12.

REFERENCES (Journal, Volume, page, year) Attach copies/reprints if possible.
Pitt, J.I. The genus Penicillium and its teleomorphic states Eupenicillium and Talaromyces. Academic Press: London 1979(80) pp. 334-336

RECOMMENDATIONS FOR MAINTENANCE & PRESERVATION
Growth medium: Czapek-Dox
Incubation temperature: 25°C
Incubation time: 7-10 d
Light requirement/pH etc. n/a
Subculative period: 6 months

Please tick appropriate box(es)

Freeze drying	✓	Water storage	☐
Liquid nitrogen storage	✓	Soil storage	☐
Oil storage	☐	Silica gel storage	☐
Other - please specify			

FOR CMI USE ONLY
Sporulation delayed after freeze drying

Figure 4. Accessions form used for cultures at the Commonwealth Mycological Institute (CMI).

completing the data matrices on strains. CMI has been fortunate in being able to secure sufficient support from the UK Department of Trade and Industry to enable additional staff to be employed to check on and build up strain data.

Within the fungi, the yeasts are the most completely documented group with respect to their physiological and metabolic attributes. This situation has arisen because (1) their biochemical activities are of immense economic importance in brewing and related industries, and (2) biochemical tests are utilized routinely in the identification of species (Barnett, Payne and Yarrow, 1983). For other fungi, many useful references to papers reporting biochemic-

al and other properties pertinent to species of biotechnological importance are included in the *Compendium of Soil Fungi* (Domsch, Gams and Anderson, 1980); the compilations of fungal metabolite data by Turner (1971) and Turner and Aldridge (1983) have already been referred to. Although the strains used by workers whose data are compiled in such reference works may not be available, and problems of misidentification occur, at least they can provide some indication of fungi with particular properties or products.

INFORMATION AVAILABILITY

Information on the names of isolates held in the various Collections maintaining fungi is currently available through the *World Directory* (*see* page 426) and individual Collection printed and machine-readable catalogues. The need to make detailed strain data internationally available has been recognized for some time (Krichevsky and Norton, 1976), and while it is pleasing to note that some progress in this direction is being made both nationally and internationally (*see* page 427), it is clear that this question is currently a major constraint to the utilization of the already existing resource base.

SERVICE DEVELOPMENT

Although the range of ancillary services which can be provided from Culture Collections is considerable (pages 420–433), and examination of *Appendix A* will show that only a very small number of Collections are in a position to offer many of these, i.e. the resource is being developed to only a fraction of its potential. Even the capacity to supply cultures is frequently curtailed by a shortage of personnel.

Government departments concerned with the development of biotechnologically based industries need to be appraised of the situation so that support of the type currently being given to CMI by the UK Department of Trade and Industry can be provided. The costs are modest in comparison to the potential of the industry.

FINANCE

The importance of Culture Collections to biotechnological advances is being increasingly recognized in temperate regions and Government support for Collections is being increased (e.g. Kirsop, 1983). However, the significance of such a fundamental resource is not always adequately recognized. For example, in the review of the potential for biotechnology in developing countries edited by Sawyer (1984), the significance of this resource was almost entirely overlooked.

Security of on-going finance is essential for Collections whose main aim is the long-term conservation of strains. Difficulties in funding have repeatedly been stressed at conferences concerned with Culture Collections (e.g. Rogosa, 1981). The situation is particularly acute for small Collections built up by

individuals in college and university departments or research institutes that do not have the maintenance of such Collections as an objective; these collections are often highly specialized and immensely important but, when the individual retires, may be lost entirely unless adequate provision has been made to transfer them elsewhere.

Provision for the cost of preservation of cultures is also not normally made in research grants to colleges and universities. This situation needs to be recognized and rectified so that Collections are able to ensure that strains which are often isolated at considerable cost, and cited in publications, can be kept without placing impossible pressures on existing Collection resources.

The sale of cultures and provision of ancillary services to industry can make significant contributions to the running costs of a Collection, but are not likely to meet the full economic cost of a collection in the foreseeable future. Although some ancillary services can, however, be expected to become self-financing, financial assistance will always be needed while services are being developed and being advertised to potential users.

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Appendix A

Appendix A. Information on the holdings and services of 73 Culture Collections including fungi

Note: This information has been compiled from a questionnaire sent out in October 1984 and is not exhaustive. This list should be supplemented by those of the International Mycological Congress (1971), Onions (1978), McGowan and Skerman (1982) and European Culture Collection Curators' Organization (1984).

Country	Acronym[1]	Name & Address	Founded	Strains[2]	Groups[3]	Staff[4]	Records[5]	Preservation[6]	Availability[7]	Services[8] (Servicing)[9]	Remarks
Australia	AWRI	Australian Wine Research Institute Culture Collection, Waite Road, Urrbrae, SA 5064	1955	153	Y(153)	1+0	A	L	F*,S	R,IN,CL (I,T,A,M)	*To educational institutions
	DBR	CSIRO Starter Culture Collection, P.O. Box 20, Highett, Victoria 3190	1951	4	A(4)	1+1	A	R	S	I (I,T)	
	DMPMC	Department of Microbiology, University of Western Australia, Queen Elizabeth II Medical Center, Nedlands, WA	1966	7	Y(7)*	1(P/T)+O		L	F	(T,M)	*'Typed' strains in the collection; there are also 44 wild fungal strains and 50 of yeasts (local sources)
	WACC	State Health Laboratories, Medical Mycology, Box F312, G.P.O., Perth, WA 6001		306	Z(16), B(20), A, D(220), Y etc. (50)	4+4		R,T,W,L			A diagnostic laboratory with ancillary collection
	DWT	Forestry Commission of New South Wales, P.O. Box 100, Beecroft 2119, NSW	1964	250	M(40), B(120), A(20), D(90)	1+0		R,O	F	I,R,B (Forestry & Forest Products, I)	Computer facilities being installed at present. Computerized records available in 1985
	FRR	Food Research (CSIRO), Ryde, P.O. Box 52, North Ryde, NSW 2113	1969	3500	Z(50), A(550), D(2800), Y(100)	2+½		R,G,L,N	F,E,S	I,R,C,IN,T,CL (Food Industry, I,A,T,M)	

	IMR-RNSH	Australian National Reference Laboratory in Medical Mycology, Royal North Shore Hospital, St. Leonards, NSW 2065	1949	810	Z(24), AD(666), Y(120)	2+0	A	T,O,G	F	I,R,C,IN,T (M,T,A)	
	MRL	Materials Research Laboratories Collection of Microfungi, M.R.L., P.O. Box 50, Ascot Vale, Victoria 3032	1945	950	A(100), D(850)	1+0		R,O,L	F,E	C,MT,B (Mould-Growth Testing, I,T,A,M)	
	QA	Plant Pathology Branch Culture Collection, Dept. of Primary Industries, Meiers Road, Indooroopilly, Qd. 4068		513	M(63), Z(3), A(22), D(424)	1+1		O,W,L,N	F	I,R,IN (A, Taxonomy, T,I,M)	
	WA	Plant Research Division Culture Collection, Dept. of Agriculture, South Perth, WA 6151	1954	2952	M(200), Z(12), B(60), A(400), D(2200), Y(80)	?	A,B(1–3)	O,L	F	R,IN,T (A,T,I,M)	
Brazil	IAL	Av. Dr. Arnaldo, 355-CEP: 01246, Sao Paulo	1968	154	Z(5), D(74), Y(62), Other(13)	2+2	A(1–2)	T,W	E,S	I,R,C,IN,T,CL (M,T,I)	
Canada	NRC	National Research Council Culture Collection, Division of Biological Sciences, NRC, Ottawa K1A 0R6	1954	1300	Y	0+1	B(1)	L,N	F	I (Government, I,T,A,M)	Primarily an in-house collection
	WFPL	Culture Collection of Wood-inhabiting Fungi, Forintek Canada Corp., Western Laboratory, 6620 N.W. Marine Drive, Vancouver, British Columbia, V6T 1X2	1920	2027	Z(13), A(134), D,Y,B(1550)	1+2	A	R,O	F,E,S	R,MT,B (Research, I,T,A,M)	Applied and pure mycology related to forest products and biotechnology

Country	Acronym[1]	Name & Address	Founded	Strains[2]	Groups[3]	Staff[4]	Records[5]	Preservation[6]	Availability[7]	Services[8] (Servicing)[9]	Remarks
Canada (cont'd)	UAMH	University of Alberta Microfungus Collection & Herbaria, Dept. of Medical Microbiology*, 1–31 Med. Sci. Edmonton, Alberta 2H7. [*Being transferred]	1960	5000	Z,B,A,D,Y	4+8	A,B(1–2)	L	F,E,S	I,R,C,IN,T,MT (A,I,M,T)	
	TPHL	Ontario Ministry of Health, Central Lab., Box 9000, Terminal 'A', Toronto, Ontario M5W 1R5	1952	1443	Z(16), B(1), A(62), D(1116), Y(248)	2+5		R,O,W	F	I,R,C,IN,T (M,T)	
	FSC	Fredericton Stock Cultures, P.O. Box 4000, Fredericton, New Brunswick E3B 5P7		780	B(593), A(109), D(62), Various (15)	?	A	R	F	I (Forestry)	
	EFFPMI	Forest Pest Management Institute, P.O. Box 490, Sault Ste Marie, Ontario P6A 5M7	1960	*c.* 150	Z(100), D(50)	1+1	B(1)	R,T,N	F	I,C,IN	Restricted to entomogenous fungi
	DMUM	Department of Microbiology, University of Manitoba, Winnipeg, R3T 2N2	1967	24	Z(1), A(10), D(13)	?		L,N	F	R (T)	
	DMG	Department of Microbiology, University of Guelph, Guelph, Ontario N1G 2W1	1905	200	M(1), Z(17), B(16), A(11), D(67), Y(88)	2+0		R,T,O,L	F	C (T,A,I, in-house research)	
	DFF	Pacific Forest Research Centre, 506 West Burnside Rd., Victoria, B.C. V8Z 1M5	1942	129	B(129)	0+1		R,T	F	I (Forestry, T)	

	CCFC	Canadian Collection of Fungus Cultures, Biosystematics Research Institute, Wm. Saunders Building, Agriculture Canada, Ottawa, K1A 0C6	1974	8245	M(40), Z(285), B(4243), A(955), D(2722)	1+2		R,T,O,L,N*	F,E	I,R,C,IN,T (A, Research, I,T,M)	*New liquid nitrogen system will be installed 1985. Maintains Brodies' Nidulariales and Noble's wood rot fungi subcollections
China	CCCCM	Culture Collection Department, Institute of Microbiology, Academia Sinica, Beijing	1952	1635	MZ(378), B(84), A(121), D(707), Y(345)	7+18	A	T,O,L,N	E,S	I,R,T (A,I,M,T)	
Czechoslovakia	IEM	The Czechoslovak National Collection of Type Cultures, Šrobárova 48, 100 42 Praha 10	1947	115	A(2), D(77), Y(36)	2+3	A	T,L,N	F,E	P,I,R,C,IN,T,CL (M,T)	
	CCY	Czechoslovak Collection of Yeasts, Institute of Chemistry of the Slovak Academy of Sciences, Dúbravská cesta 9, 84238 Bratislava	1942	3405	Y(3405)	4+3	A,B(2)	R,T,O,L,N	F,E,S	P,I,R,C,IN,T,CL (A,I,M,T)	Includes seven other smaller collections: RIVE, RIBM, DMUP, DBM, RIFIS, CCPY, DGUB[1]
	CCM	Czechoslovak Collection of Microorganisms, J.E. Purkyně University, tř. Obránců míru 10, 662 43 Brno	1963	800	A(30), D(770)	1+1	A	O,W,L,N	E,S	I,R,C,IN,T,B (T,I,A)	
	CCF	Culture Collection of Fungi, Department of Botany, Faculty of Sciences, Benátská 2 St., 12801 Prague 2		1176	Z(175), A(81), D(920)	3+1	A	R,T,L	F,E,S	I,R,C,IN,T,B (I,T, Research, M,A)	

Country	Acronym[1]	Name & Address	Founded	Strains[2]	Groups[3]	Staff[4]	Records[5]	Preservation[6]	Availability[7]	Services[8] (Servicing)[9]	Remarks
Czechoslovakia (cont'd)	CCBAS	Culture Collection of Basidiomycetes, Department of Experimental Mycology, Institute of Microbiology, Czechoslovak Academy of Sciences, Krč. Vídenská 1083, 142 20 Prague 4	1959	500	B(500)	1+1 (P/T)	A	R,T,O	E,S	R,C,IN,T,CL (Investigation, T,M,I,A)	Part of CCM. 215 species (383 dikaryons, 117 monokaryons)
France	UCLAF	Roussel UCLAF, 111 Route de Noisy, 93 230 Romainville		190	Z(8), D(62), Y(120)	1+1		R,L,N	F*	R (I,A)	*Availability depending on patent and industrial situation
	LCP	Laboratoire de Cryptogamie du Muséum National d'Histoire Naturelle, 12 Rue de Buffon, 75005 Paris		2500	Z(100), A(100), D(2300)	2+2	A,B	T,O,L,N	F,S	I,R,C,IN,T,CL,B (I,T,A,M)	
Germany	MW	Friedrich-Schiller-Universitat Jena, Sektion Biologie, Pilzkulturensammlung, Freiherr-vom-Stein Allee 2, Postfach 16,329, DDR-5300 Weimar		5337	Z(84), B(1212), A(532), D(3478), Y(31)	2+3	A	R,T,N	F*,E,S	I,R,T (A,I,M,T)	*Smaller quantities
	FIE	Akademie der Landwirtschaftswissenschaften der Deutschen Demokratischen Republik, Institütf. Pflanzenschutz forschung, Stahnsdorfter Damm 81, Kleinmachnow DDR-1532		498	Z(15), B(195), A(138), D(86), Y(45), M(19)	1+1	A	O	F	(A,T,I, Biochemistry)	

	DSM	German Collection of Microorganisms, DSM, Grisebachstr. 8, D-3400 Göttingen, FRG	1968	1210	M(43), Z(100), B(147), A(163), D(745), Y(300), Myxomycetes (12)	6+12	A(2-3)	O,L,N	E,S	I,R,C,IN,T,P (T,I,A,M)	
	CCDAM	Institut für Mikrobiologie und Landeskultur Mikrobiologie, Senckenbergstrasse 3, 6300 Giessen FRG	1971	208	Z(32), A+D(153), Y(23)	1+½		R,T,L	F	I,R,C (Research, A,T,I)	
	BLWG	Bayerische Landesanstalt für Weinbau und Gartenbau, Residenzplatz 3, D-8700 Würzburg FRG	1962	900	Y(900)	?		R	E	(A,I,T)	
	BBLF	Institüt für Pflanzenschutz im Forst, Messeweg 10/12, 3300 Braunschweig FRG	1952	600	B(200), A(200), D(200)	1+0	T,O	F	(T)		
Hungary	HMGB	Department of Microbiology, University of Horticulture, Somloi ut 14-16, H-1118 Budapest	1974	250	Z(23), A(44), D(31), Y(152)	3+2	A	R,T,O,L,N	F	I,R,C,IN,T (T,I)	Centre of the Hungarian Microbiological Gene Bank
India	ITCC	Indian Type Culture Collection, Division of Mycology and Plant Pathology, Indian Agricultural Research Institute, New Delhi 12	1945	2177	M(20), Z(131), B(169), A(256), D(1529), Y(72)	3+1	A	O,R,S,T,G,W	F,E,S	C,I,IN,R (A,I,M,T)	
Ireland	GCC	Guinness (Dublin) Culture Collection, R&D Dept., A. Guinness Son & Co. (Dublin) Ltd, Eire	Early 1900s	363	Y(362)	?	?	Limited			Essentially private but cultures available on limited selective basis

Country	Acronym[1]	Name & Address	Founded	Strains[2]	Groups[3]	Staff[4]	Records[5]	Preservation[6]	Availability[7]	Services[8] (Servicing)[9]	Remarks
Italy	IMAT	Yeast Collection, Universita' degli Studi di Perugia, Istituto di Biologia Vegetale, Sezione di Microbiologie, Borgo XX Giugno 74, 06100 Perugia		2500	Y(2500)	2+2	B(1)	R,T,L	F,E,S	I,R,C (I,A,T)	Formerly Wine Yeast Collection, Istituto di Microbiologia Agraria e Tecnica.
	IPV	Istituto Patologia Vegetale, via Celoria 2, 20133 Milan	1949	423	M(15), Z(5), B(26), A(116), D(246), Y(15)	3+1		W,L	F,E	R,IN,T,MT (A,T)	
Japan	IFO	Institute for Fermentation, 17-85 Juso-honmachi 2-chome, Yodogawa-ku, Osaka	1944	9585	M(155), Z(445), B(1121), A(1122), D(3458), Y(2284)	4+6	A,B	R,T,O,L	E,S	R,C,IN,T,CL (A,I,T,M)	
	IAM	IAM Culture Collection, Institute of Applied Mycology, University of Tokyo, 1-1-1 Yayoi, Bunkyo-ku, Tokyo 113		791	Z(64), B(15), A(116), D(361), Y(235)	2+3	A	T,O,W,L	E,S	C,IN (Research, I,T,A,M)	
Netherlands	CBS	Centraalbureau voor Schimmelcultures, P.O. Box 273, 3740 AG Baarn	1904	28 300	M(700), Z(1000), B(4100), A+D(19 100), Y(3500)	15+19	A,B(2)	T,O,W,G,L,N	E,S	P,I,R,C,IN,T,CL,B (T,I,A,M)	
	RIPO	IPO-Collection of Fungal Pathotypes, Research Institute for Plant Protection, P.O. Box 9060, 6700 GW Wageningen		1317	Z(39), B(1005), D(273)	1+1	A,B(1)	R,T,O,S,L,N	F,S	I,R,C,IN,T (A,T,I)	Maintained to serve resistance breeding (cereals, potatoes, vegetables); *Puccinia striiformis* strains

New Zealand	DBVU	Victoria University of Wellington, Botany Department, Private Bag, Wellington	1965	555	M(5), Z(50), B(10), A(150), D(300), Y(40)	1+0	A	O	F*,E,S	I,R,C (T,A,I)	*To researchers
	NZFS	Forest Research Institute Culture Collection, Private Bag, Rotorua	1948	150	M(19), Z(2), B(63), A(18), D(46), Y(2)	1+1		O	F	I,R (Forestry)	
	PDDCC	DSIR, Mt. Albert Research Centre, Private Bag, Auckland		*c.* 2000		1+1	A,B	O,L	F,E,S		
Philippines	BIOTECH	BIOTECH, UP at Los Baños College, National Institutes of Biotechnology and Applied Microbiology, Laguna 3720	1981	117	Z(3), B(49), D(6), Y(58)	1+0		R,O	F*	R,C,IN (Research,T)	*Within the Institute only
	FCUP	Fungal Culture Collection, Department of Plant Pathology University of the Philippines at Los Baños College, Laguna, Philippines	1972	*c.* 300	Z(20), B(75), D(180)	?		R,O	F,E,S	I,R (T,A, Research, I)	
	NIST	Culture Collection Strain Improvement Project, National Institute of Science & Technology, Pedro Gil, Metro Manila	1945	82	Y, Other	5+1	A	R,S	E	R,C,IN,CL (A,I,M,T)	
	UPCC	University of the Philippines Culture Collection, Natural Sciences Research Institute, Diliman, Quezon City 3006	1970	428	M(6), Z(46), B(8), A(26), D(272), Y(70)	1+0	A,B(1–3)	R,T,O,L	F,E,S	I,R,C,T,MT (T,I,A,M)	Includes marine & estuarine fungi
Poland	IPF	Collection of Industrial Microorganisms, Institute of Fermentation Industry, Rakowiecko 36, Warsaw		338	D(77), Y(261)		A	R,T,O,L	E,S	R,C (I,A,T)	

Country	Acronym[1]	Name & Address	Founded	Strains[2]	Groups[3]	Staff[4]	Records[5]	Preservation[6]	Availability[7]	Services[8] (Servicing)[9]	Remarks
Roumania	ICCF	ICCF Collection of Industrial Microorganisms, 112 Soseaua Vitan, Bucharest 3	1960	9	A(5), D(3), Y(1)	4+6		R,T,O,L,N	E,S	I,R,T,CL,MT (I,A,M,T)	
Singapore	USDB	Botany Department Culture Collection, National University of Singapore, Kent Ridge, Singapore 0511	1950	338	M(6), Z(24), B(11), A(141), D(126), Y(30)	1+1	B(1,3)	R,T,L		R,C,IN,T,MT,B (T, Research)	
Spain	CCMCU	Culture Collection of Microorganisms, Department of Microbiology, Ciudad Universitaria, 28040 Madrid	1960	700	Y(700)	2+2	A	T	E	R (T,I,A)	Subcollection yeasts (MCYC)
	CECT	Coleccion Espanola de Cultivos Tipo, Departamento de Microbiologia, Facultad de Ciencias Biologicas, Burjasot (Valencia)	1961	354	M(4), Z(16), B(4), A(28), D(122), Y(180)	2+0	A1,3	T,L	F,E,S	I,R,C,IN (University & National Research Council Research, I,M,T,A)	
Sri Lanka	DBUK	Department of Botany, University of Kelaniya, Kelaniya	1968	70	Z(7), A(4), D(29), Y(25), Other(5)	3+2		R,S,L	F	R,I,T (T)	
Switzerland	ICIDTC	Centre de Collection de Types Microbiens, CCTM, Rue du Bugnon 44, 1011 Lausanne		51		1+2	A	L	F,E,S	I (M,T)	

Thailand	CHULA	Microbiology Department, Faculty of Science, Chulalonghorn University, Bangkok 10500		67	M(3), Z(30), B(10), A(5), D(15), Y(4)	?		R,O,S,W,L	F,E	P,R,C,MT (T)	
	MDMU	Microbiology Section, Department of Science Service, Rama VI Street, Bangkok 10400	1975	20	A(5), Y(15)	2+0		R,T,O	E	R (I)	
UK	AP	Aquatic Phycomycete Culture Collection, Department of Botany, University of Reading, Reading, Berkshire RG6 2AS	1956	*c.* 800	M(*c.*800)	1(P/T)+0		R,T,W	F,E	T	Strains to be listed in CMI's catalogue in 1985 and then also available for sale
	FPRL	National Collection of Wood Rotting Fungi, Building Research Establishment, Summerleys Rd., Princes Risborough, Aylesbury, Buckinghamshire HP17 9PX	1927	524	B(513), A(11)	1(P/T)+1 (P/T)	A	R,O	E,S	I,R,C,IN,CL,MT,B (I, University Research, T,A,M)	
	IMI[CMI]	Culture Collection, Commonwealth Mycological Institute, Ferry Lane, Kew, Surrey TW9 3AF	1920	11 171	M(374), Z(835), H(221), A(2462), D(7251), Y(28)	5+6	A,B	R,O,S,W,G, L,N	E,S	P,I,R,C,IN, T,CL,MT,B (A, CMI staff, I,M,T)	Includes UK National Collection of Fungus Cultures (NCFC) and Biodeterioration Centre. Funded by 28 Commonwealth Governments. UNESCO, MIRCEN Supported by herbarium (300 000 specimens) and 16 taxonomists
	KCCB	Kemp *Coprinus* collection, Department of Botany, University of Edinburgh, Edinburgh EH9 3JH	1970	1500	B(1500)	1(P/T)+0		R,T	F,E	I,R,IN (T)	Includes 50–70 *Coprinus* species

Country	Acronym[1]	Name & Address	Founded	Strains[2]	Groups[3]	Staff[4]	Records[5]	Preservation[6]	Availability[7]	Services[8] (Servicing)[9]	Remarks
UK (cont'd)	NCYC	National Collection of Yeast Cultures, Food Research Institute, Colney Lane, Norwich, NR4 7UA		1550	Y(1550)	3+1	A,B (1–3)	L,N	E,S	P,I,R,IN,T (I,T,M,A)	Much information on industrially important properties available
	PPCCE	Culture Collection, Dept. of Biological Sciences, Portsmouth Polytechnic, King Henry Building, King Henry I St., Portsmouth PO1 2DY	1971	1500	M(few), Z(few), B(few), A(1300), D(200), Y(few)	P/T	A	T,W	F,S	I,R,C,T,B (Research, T,I)	All are marine or freshwater fungi
USA	NRRL	Agricultural Research Service Culture Collection, NRRL, 1815 N. University, Peoria, Ill. 61604	1940	33 600	Z(1000), B(100), A(1500), D(18 000), Y(13 000)	?	B(1)	R,L,N	F	P,I,R,C,IN,T (I,A,T,M)	No catalogue available
	LMS	Carolina Biological Supply Company, 2700 York Road, Burlington, North Carolina 27215	1927	82	M(10), Z(12), B(7), A(10), D(30), Y(3), Gymnomycota (3)	1+2	A,B(1)	R,T	S	C,IN (T,M,I,A)	
	ATCC	American Type Culture Collection, 12301 Parklawn Drive, Rockville, Md. 20852	1925	18 000	M,Z,B,A,D,Y	15+15	A,B(1–3)	L,N	S	P,I,R,C,IN, T,CL,B (I,M,A,T)	
	FGSC	Fungal Genetics Stock Center, Humboldt State University Foundation, P.O. Box 4300, Arcata, California 95521-2400	1960	5000	A(5000)	1+1	A	G,L,N	S*	I (Academic Research, T,I)	*Waived if funds not available Strains include: *Neurospora* spp. (primary interest), *Aspergillus nidulans* & *Sordaria fimicola*

	DLR	Mycological Culture Collection, Wadsworth Center for Laboratories & Research, New York State Department of Health, Albany, NY 12201		804	Z(44), A(5), D(352), Y(403)	2+2		R,T,O,L	F	I,R,C,IN,T (M,T,I,A)	
	UPJOHN	Infectious Diseases Research, The Upjohn Company, Kalamazoo, MI 49001	1954	2500	M,Z,B,A,D,Y	1+1	B(1)	N,S	F	I,C,R,IN (Antibiotics Research, A,I,M,T)	Some cultures restricted. Genetic strains maintained. Catalogue in-house only.
USSR	VKM	All-Union Collection of Microorganisms, Institute of Biochemistry and Physiology of Microorganisms, USSR Academy of Sciences, Pushino-on-Oka, Moscow Region 142292	—	4796	M(98), Z(610), B(121), A(207), D(1760), Y(2000)	5+3	A	L,N,O,R,S, T,G,W	F,E	C,R (Research, T,I,A)	Identification by special arrangement

[1]Acronyms as used by the World Data Center (McGowan and Skerman, 1982).
[2]Includes only strains of filamentous fungi and yeasts held.
[3]A = Ascomycotina, B = Basidiomycotina, D = Deuteromycotina, M = Mastigomycotina, Y = yeasts, Z = Zygomycotina; numbers in brackets are the numbers of each of these groups held.
[4]Staff are given in the form 'X + Y' where X = number of scientists (graduates) and Y = number of technicians and clerical assistants; P/T = part-time.
[5]A = Catalogue available; B = Records computerized (1 = searchable, 2 = metabolic data included, 3 = growth requirements included).
[6]L = lyophilization (freeze-drying), N = liquid nitrogen, O = mineral oil, R = refrigeration, S = soil, T = frequent transfer, G = silica gel, W = water.
[7]F = free, E = exchange, S = sale.
[8]B = biodeterioration services, C = consultancy, CL = chemical laboratory, I = identification, IN = information, MT = mould-growth testing, P = International Depositary for Patent Strains, R = research, T = training.
[9]Main users of collection, in order of importance for each collection: A = agriculture, I = industry, M = medicine, T = teaching.