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The role of public biological resource centers in providing a basic infrastructure for microbial research

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Abstract

Public collections of microorganisms have been established since the late 19th century, and currently 573 service collections are registered at the World Data Center for Microorganisms (www.wdcm.org). All together, they hold more than 1.5 million microorganisms.

By implementing guidelines compiled by the Organisation for Economic Co-operation and Development (OECD), many public service collections evolve into professional ex situ repositories of biodiversity and distribution nodes for known, validated and precisely identified microbial resources and associated information to legitimate end-users. These Biological Resource Centers (BRCs) may be the preferred mechanism for the appropriate exploitation of microbial resources by offering the guarantee of accessibility and of transparency of supply, taking into account all relevant regulations and stakeholders' rights, as required by the Convention on Biological Diversity (CBD). Scientists are encouraged to deposit researched microbial material at public BRCs to contribute to the Science (semi-) Commons and maximize the impact of prior knowledge.

BRCs are essential infrastructures supporting the future of life sciences and biotechnology.

Keywords: Biological Resource Center (BRC); Research infrastructure; Biodiversity; Microbial resources; Ex situ preservation; Quality control; Regulated access; Interoperability; Networking; Microbial commons

1. Introduction

Microorganisms represent a huge biodiversity which is essential for life on this earth and which provides a quasi-unlimited resource for development of downstream biotechnological applications. Researching microbial diversity is a main topic in science, and vast public and private budgets are being invested in isolating, characterizing and understanding this diversity for the progress of science and the benefit of humankind.

Research results are carefully preserved in thousands of scientific papers a year, accessible to the scientific community and available in hardcopy and/or electronic format.

However, accessibility of the ex situ microorganisms investigated is uncertain, depending in many cases on the time and goodwill of the individual scientists involved. Access may even be denied as a strategic secrecy policy based on a potential economic value. And generally, long-term availability can rarely be assured by the research groups or their host institutes. Depositing such valuable living resources at public Biological Resource Centers (BRCs) (culture collections) to ensure open but regulated availability is not yet standard routine practice.

For example, a small survey of 8 European microbiology journals carried out in the framework of the European EMbaRC

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project (see Networking) showed that in 2008, 1261 papers on prokaryotic cultures (non-type strains) were published, involving 20172 isolates of which only a minute fraction (less than 1%) were deposited at a public BRC to ensure their long-term availability and controlled quality (Stackebrandt, 2009, personal communication). Also, less than half (47%) of the more than one-thousand taxonomically and ecologically diverse bacterial strains of which the whole genome sequence is publicly available to date (Gold Genomes On Line Database v 3.0, November 2009) (Liolios et al., 2009) can be retrieved from a public BRC for further studies, such as linking of genome to transcriptomics, proteomics, metabolomics and other expressed manifestations of the genome in the native cell.

Lacking this biological material hampers acceleration of progress in science, as it impedes building on previous knowledge and past discoveries, and in fact makes the value of many published data questionable, since independent confirmation is not possible.

This situation does not fit into the spirit of global research (semi-) commons of the 21st century, and is increasingly contested by scientific groups and journals. Several scientific journals insist on the public availability of representatives (key strains) of the microorganisms described in the manuscripts they publish, and some require this through a public service collection. Moreover, in bacterial taxonomy, the International Committee on Systematics of Prokaryotes, since 1999, has imposed mandatory deposition of type strains in at least two public service culture collections located in different countries before a bacterial name is validly published (Labeda and Oren, 2008). In analogy with this initiative, it is advocated that sequenced bacterial strains be saved from extinction by depositing them in at least two major public service culture collections (Coenye and Vandamme, 2004; Field and Hughes, 2005; Ward et al., 2001).

2. Need for public BRCs

Incentives for scientists to contribute to research (semi-) commons by depositing strains may appear minor at first sight, but, for example, with respect to citations, depositing cultures in a public BRC has a significant selective effect (ca. 100% more citations of papers in which strains have a collection deposit number) and a robust marginal effect (ca. 50–125% boost in citation after later deposit) (Stern, 2008). In this context, the role of research institutes, major research initiatives and their research funding bodies in adopting a policy of stimulating deposit of biological material investigated is of great importance.

Awareness of governments as to the role of public service culture collections and to their responsibility in supporting these infrastructures has increased under the impetus of the Organisation for Economic Co-operation and Development (OECD). The OECD consensus report "*Biological Resource Centres: underpinning the future of life sciences and biotechnology*" (OECD, 2001; www.oecd.org/dataoecd/55/48/2487422.pdf) clearly acknowledges and emphasizes that sustainable access to biological resources requires professional repositories and distribution nodes, collectively called BRCs. Culture collections that reach the BRC status sensu OECD meet the high standards of quality and expertise demanded by the international community of scientists and industry, carry out R&D activities on the biological resources maintained, and act as repositories of biodiversity and of biological resources related to protection of intellectual property. Hence BRCs provide an essential infrastructure for life sciences and biotechnology by preserving and making available known, validated and precisely identified biological resources and associated data. It should be noted that many BRCs, in addition, also offer their scientific and technological expertise and know-how to academia and industry, by performing analyses and research on a service basis.

The benefits of conservation of biological resources were also emphasized by the Convention on Biological Diversity (CBD, 1993; www.cbd.int/doc/legal/cbd-un-en.pdf), which highlights the need for BRCs as ex situ conservatories for biodiversity. BRCs may also be the preferred means of appropriate exploitation of biological resources and offer the guarantee of accessibility and transparency of supply, as required by the CBD.

Local, regional and global exchange of microbial material is governed by many national and international rules, laws and regulations on issues such as biosafety and biosecurity, import and export permission, phytosanitary regulations, international road and air transport regulations, intellectual property rights, as well as by specific material transfer agreements (MTAs) related e.g. to the country of origin and/or the depositor. BRC staff members are professionals who routinely deal with complex regulatory requirements governing the legitimate and safe transfer of microbial material.

It is obvious that some degree of harmonization in the operation of the diverse existing BRCs is recommended and beneficial both for the BRCs themselves and for the providers/depositors and recipients/users of biological material. This trend could ultimately converge into a global BRC network, or GBRCN (see Networking).

One of the first internationally approved set of guidelines covering all aspects of culture collection activity was published by the WFCC (World Federation for Culture Collections, 1990). Recent guidelines on operation of a BRC are provided amongst others by the OECD document "*Best Practice Guidelines for BRCs*", agreed to by OECD member countries in March 2007, covering preservation of resources, quality management, biosecurity, data management, and capacity building (OECD, 2007; www.oecd.org/dataoecd/7/13/38777417.pdf). The Bonn Guidelines 2002 focus on "*Access to Genetic Resources and Fair and Equitable Sharing of Benefits Arising out of their Utilization*" (Convention on Biological Diversity, 2002; www.cbd.int/doc/publications/cbd-bonn-gdls-en.pdf). A voluntary code of conduct in this respect is offered by MOSAICC (*Microorganisms Sustainable Use and Access Regulation International Code of Conduct*), a concerted action with the support of the Directorate General XII for Science, Research and Development of the European Commission (see Supply policies).

3. Accession policy, preservation and quality control

3.1. Procedure for accession

BRCs have an accession policy defining the biological material to be accepted. This is based mainly on specific acceptance criteria, technical and scientific specialist expertise and the requirements of the CBD. In order to avoid unnecessary duplication of efforts, BRCs are encouraged to be complementary, although for certain groups of organisms, difficult to grow or preserve, duplication is a sound precaution against loss.

For each strain presented to a BRC for public deposit, the depositor must complete and sign an accession form, which documents the material and provides data on origin and isolation (such as country of origin, biological origin, date of isolation), properties of the strain, identity, growth requirements, methods of preservation, hazard information, other collection numbers, bibliographic references and database links. Most of this information becomes freely available to the scientific community through electronic collection catalogues. In case the material is deposited under specific terms or conditions, the BRC will add these to its own MTA when supplying samples.

To each deposited strain, a unique identifier (accession number) is allocated. This identifier is never reassigned even if the strain is later discarded.

Upon receipt of the biological material, a quality control procedure is started (see 3.3).

For handling biological material, the BRC has qualified personnel who work in laboratories with the appropriate containment level and equipped with appropriate microbiology safety cabinets, complying with the hazard risk of the material. The World Health Organization classifies biological agents into four groups, described as follows (WHO, 2004):

- Risk Group 1 *(no or low individual and community risk)*: A microorganism that is unlikely to cause human or animal disease.
- Risk Group 2 *(moderate individual risk, low community risk)*: A pathogen that can cause human or animal disease but is unlikely to be a serious hazard to laboratory workers, the community, livestock or the environment. Laboratory exposure may cause serious infection, but effective treatment and preventive measures are available and the risk of spread of infection is limited.
- Risk Group 3 *(high individual risk, low community risk)*: A pathogen that usually causes serious human or animal disease but does not ordinarily spread from one infected individual to another. Effective treatment and preventive measures are available.
- Risk Group 4 (*high individual and community risk*): A pathogen that usually causes serious human or animal disease and that can be readily transmitted from one individual to another, directly or indirectly. Effective treatment and preventive measures are not usually available.

3.2. Preservation

The biological materials preserved at a BRC may be highly diverse (e.g. viruses, bacteria, fungi, cell lines). A selection of appropriate preservation methods is made based on recommendations of the depositor and/or previous experience.

In compliance with WFCC and OECD guidelines, organisms are preserved preferably by two different methods, one of which, at least, is a long-term preservation method such as freeze-drying, liquid-drying or cryopreservation (for example at −80 °C, in liquid nitrogen vapor or submerged in liquid nitrogen), or sometimes preservation under mineral oil. Subcultivation may, on occasion, be the only means of preservation, especially for recalcitrant fungi and algae (Kirshop and Doyle, 1991). Performance of the methods should correspond to the following quality control criteria:

- Viability of a sufficiently high fraction of the preserved culture
- Genetic stability of the preserved culture
- No contaminant in the preserved culture
- Authenticity of the preserved culture

Cryopreservation and freeze-drying are the most widely used techniques for preservation of biological materials (Day and Stacey, 2007). For large collections, freeze-drying is the method of choice for long-term preservation of microorganisms, since freeze-dried biological materials in vacuum-sealed ampoules can be easily stored and transported at ambient temperature (Morgan et al., 2006). Freeze-drying consists of a series of processes aimed at reducing the metabolism to practically zero by drying, with a minimal effect on viability. The result should enable storage of organisms at a practical temperature and guarantee the successful revival after a long period. In practice, a drop in viability of 1 log or more is observed after freeze-drying of delicate organisms. In contrast to freeze-drying, freezing at ultra-low temperatures is in most cases not accompanied by a significant drop in the suspension titer after preservation and generally results in higher genetic stability of the preserved cultures (Safronova and Nokinova, 1996). This is an efficient and reliable means of maintaining stock cultures of a broad range of microorganisms, but this method is expensive for the BRC due to higher maintenance and handling costs, and for the recipient due to higher transport costs for shipping frozen cultures on dry ice or revived agar cultures.

BRCs use documented preservation procedures and make records of key parameters to ensure reproducibility.

The biological material is stored under environmental parameters that ensure the stability of its properties. A duplicate collection is stored at a different location to avoid accidental loss.

Rehydration of microorganisms is a critical step for revival after drying, and BRCs routinely inform their users on the recommended procedure.

3.3. Quality control

In order to meet the standards of quality and expertise required by the international community of scientists and industry for the delivery of biological materials and information, BRCs perform several quality controls (OECD, 2007; Watanabe et al., 2004).

Quality controls are carried out on at least three occasions:

- Upon receipt of the original material
- After preservation of the first batch of samples
- After each subsequent new batch preservation.

Key features that are controlled are:

- Viability: the culture is grown on the medium recommended by the depositor and/or on other media if considered opportune;
- Purity: critical examination on different growth media is carried out to confirm that the culture is pure;
- Authenticity: tests are performed to assess whether the culture conforms to the description provided by the depositor, or by literature;
- Properties (if appropriate and possible): e.g. specific assays, biochemical traits, molecular characteristics, fingerprints, can be determined.

Tests are performed according to documented procedures and all results are recorded and retained for future reference.

Most culture collections supply materials and services of high standard, and over the last decade many of them have developed a formalized quality management system and are currently ISO 9001-certified or ISO 17025-accredited. A next step in quality management by BRCs is full implementation of OECD Guidelines (see also Networking).

4. Supply policies

4.1. The Convention on Biological Diversity (CBD)

Next to providing other services, the main task of public BRCs is to supply samples of their biological material and related information to the scientific community, companies, public health laboratories and other institutions entitled to use this material. In brief, they provide this vast source of material and information to the society, be it for reference, further study or commercial use. Most public culture collections holding microorganisms have evolved to BRCs in the last decade, but there are still great historical differences among the centers regarding funding, affiliation, facilities, size, staff and supply policies.

Originally, most collections facilitated the distribution of strains without any restrictions on use and reuse, and in many instances, without any charges. With time, they have developed their own access and supply rules in a quite independent way. Some have operated very informally and had no written regulations until recently; others developed a set of general standard terms and conditions. No commonly agreed procedures and conditions were applied, although culture collections have traditionally collaborated and exchanged information and strains. This cooperation must be maintained and strengthened in order to cope with the legal framework under which they have to develop their activities, and with new challenges such as those derived from the objectives of the CBD.

The CBD, which was one of the most relevant results of the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992, entered into force on 29 December 1993 and has had a strong impact on culture collections. The objectives of this Convention, to be pursued in accordance with its relevant provisions, are: '*(i) the conservation of biological diversity, (ii) the sustainable use of its components, and (iii) the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding*'.

Thus, the CBD recognizes the sovereign rights of states over their natural resources as well as the fact that the authority to grant access to genetic resources remains with national governments and is subject to national legislation. It is therefore necessary – prior to sampling/isolation – to determine whether sovereign rights/ownership of microorganisms are covered by national law in a given country, and in such a case, to obtain prior informed consent (PIC) from a competent national authority. The terms of access (including benefit sharing and further transfer of the material) are negotiated between the parties and documented in the PIC and/or in a separate material transfer agreement (MTA). Most BRCs therefore ask a depositor if a PIC was obtained for the isolate submitted for deposit, as this might affect the conditions for further supply of samples. It is, however, clear that to date, few scientists implement or are aware of this aspect of the CBD. A posteriori is not always easy to comply with CBD regulations, and in many cases it is completely impossible. As an example, the assigning of a strain to a specific origin/country may be difficult to prove because of the ubiquitous nature of microorganisms.

One of the most comprehensive initiatives for developing a tool to support implementation of the CBD at the microbial level was MOSAICC (*Microorganisms Sustainable Use and Access Regulation International Code of Conduct*) (www.belspo.be/bccm/mosaicc). It was elaborated as a voluntary code of conduct to facilitate access to microbial genetic resources and to help partners make appropriate agreements when transferring them. MOSAICC combines the need for easy transfer and the need to monitor this transfer. It provides guidelines for obtaining a PIC and for elaboration of a material transfer agreement (MTA), the terms of which are defined by both recipient and provider. It defines an MTA as '*a generic term that covers either a very short shipment document, a simple standard delivery notice, a standard invoice containing minimal standard requirements or a more detailed*

specific contract including tailor-made mutually agreed upon terms'.

The OECD Bonn Guidelines (Convention on Biological Diversity, 2002) suggest some elements for the implementation of MTAs, such as: introductory provisions such as legal status of provider and user, provisions on access and benefit sharing, and legal provisions. Regarding the latter, they mention the assignment of transfer of rights and the assignment, transfer or exclusion of the right to claim any property rights, including intellectual property rights (IPRs) over genetic resources received through the MTA. Several articles from the CBD deal with this quite controversial aspect, especially articles 16.2 and 16.5.

Most public collections/BRCs have thus far developed their own MTA for supply of samples, with occasional striking differences between them. Critical points concern IPRs and ownership.

If BRCs want to address the IPRs in their MTAs, MOSAICC makes useful recommendations for coping with this matter:

- '*To agree on the IPRs of the microbial resource and/or derived technology before investing in research and development that could lead to the commercial use of the MR or derived technology;*
- *To allocate the IPR to the inventing partner(s); and this while not necessarily excluding that other partners can, in the exceptional case of a successful commercial use of the MR and other derived technology, profit from forms of monetary compensation (royalties or other) and/or of a license on concessive or preferential terms*'.

BRCs should keep accurate and complete records of depositors, dates of deposit, if possible, the year of isolation and geographic and biological origin of isolates, and provide this information to their users to allow them to comply with the CBD. This may not be enough, as not all states that signed the CBD have designated national focal points for the different topics within the CBD, such as the Global Taxonomy Initiative (www.cbd.int/gti/), the Cartagena Protocol on Biosafety (www.cbd.int/biosafety/) and Access and Benefit Sharing (www.cbd.int/abs/). The latter has already been explained and is the third main objective of the CBD. The Global Taxonomy Initiative is also a part of the CBD. It stresses the importance of correct naming of the organisms in conservation and sustainable use. Taking into account that only a very small fraction of the microorganisms have been described, as well as the high numbers of new taxa that are being described each year (especially bacteria and archaea) and deposited in culture collections/BRCs (according to modified rule 27 and 30 of the International Code of Nomenclature of Bacteria), this represents a huge task and responsibility for BRCs. The Cartagena Protocol is a supplementary agreement to the Convention on Biological Diversity and entered into force on 11 September 2003. It is an international treaty governing the movements of living modified organisms resulting from modern biotechnology from one country to another.

MOSAICS (*Microorganism Sustainable Use and Access Management Integrated Conveyance System*) was a later EU-supported project to promote the Rio objectives that apply to biodiversity benefits in general and microbial ones in particular (http://bccm.belspo.be/projects/mosaics/documents/files/benefits.pdf). It continued setting up an integrated system to manage access to, and transfer of, microbial resources. It stressed both the need for reliable methods for evaluating (micro)biological resources, crucial when dealing with benefit sharing, as well as the need to enable tracking of these resources. Concerning the latter, MOSAICS has made recommendations on the use of unique identifiers that could be used by microbiologists working in different fields (research, commercial companies and other institutions).

If BRCs want to address ownership, an alternative framework for this issue with regard to the transfer of microbial resources and data could lie in the concept of 'bundle of rights' (Dedeurwaerdere, 2006; http://bccm.belspo.be/newsletter/18-05/bccm03.htm). According to this concept, ownership is analyzed as a 'bundle' of use and decision rights that are attributed to a number of agents (country of origin, scientists, companies, depositors, BRCs). Access, extraction, withdrawal and contribution are defined as 'Use Rights'; management, exclusion and alienation as 'Collective Decision Rights'. Full ownership implies the full bundle of rights, which applies poorly to the microbial resource itself, but which in specific cases can be applied to associated knowledge.

4.2. Types of supply policies

There exist different possibilities concerning the supply of samples from public deposits, ranging from totally open access (Microbial Commons) to the establishment of proprietary norms by the collections. Some BRCs, like the ATCC '*retain ownership of all right, title and interest in the ATCC materials…*' (sic). Concerning the scope of use, ATCC establishes that '*any commercial use of the Microbial Resource is strictly prohibited without ATCC's prior written consent*' (sic). (www.atcc.org/MaterialTransferAgreement/tabid/613/Default.aspx). In contrast to ATCC policy, RIKEN BRC (Japan) does not claim the right to transfer or assign any patents or other intellectual property rights with respect to the Microbial Resource without prior consent of the depositor, and it may distribute the biological material to recipients pursuant to the terms and conditions set forth by the depositor (www.jcm.riken.go.jp/JCM/FormM_9_howto.pdf):

- No specific terms and conditions (the depositor waives its own rights under any patents, IPR or other proprietary rights with respect to the results to be obtained by use of the Microbial Resource), or
- Specific terms and conditions are requested by the depositor. In this event, the recipient of the Microbial Resource shall obtain prior written consent on its use from the depositor.

It should be remembered that Japan is a signatory party of the CBD, whereas the USA is not.

From these examples, three conclusions can be drawn:

1. The supply conditions depend on accession criteria, which should be specified by the BRCs.
2. Only through organizations like BRCs are controlled distribution and quality possible, but:
3. If depositors or BRCs impose many restrictions, this will hamper access to the biological material by the scientific community and may lead to the development of a parallel system without control, traceability or guarantees.

4.3. A European approach to an MTA

The use of an MTA for exchange and supply of strains by the collections has been a subject of debate among the European collections for several years, and the main forums of discussion have been the annual meetings of the European Culture Collections' Organisation (ECCO). In 2009, at the XXVIII ECCO meeting in Göteborg, the first official version of the ECCO Core MTA was agreed upon (www.eccosite.org). It applies to the use, handling, distribution and any disposition of the material supplied by the collection. It reflects the maximal common position of the ECCO membership with respect to the key items: traceability, fair and equitable benefit sharing, quality, safety and security.

This core fulfils CBD requirements regarding access and benefit sharing vis-à-vis the country of origin, but it does not claim any compensation for the BRC in case of commercial benefits, nor does it address the IPRs in detail. The ECCO BRCs do not claim ownership of the biological material maintained; rather, they favor the concept of a 'bundle of rights' affecting the depositor, the BRC itself and the end user. The BRCs have several rights, i.e. the right to accession of the strains, to multiplication and storage and to further distribution of samples under the CBD regime.

To avoid unauthorized access, loss of traceability or erosion of quality of the material supplied, and to guarantee the rights of the country of origin, the ECCO Core MTA prohibits the further distribution of samples by the recipient, although a number of legitimate exchanges are explicitly defined, such as between project partners or between culture collections.

This Core MTA can be used on its own, or can be extended, for instance, if partners wish to make additional agreements for specific categories of strains and derived technology, depending, for example, on a gliding scale of value added during acquirement of the microorganisms (isolation, purification), their characterization (identification; detection of possible uses) and further development of those microorganisms and derived technology. Agreements could range from single to shared IPR ownership. Another possibility is to establish "liability rules", as formulated by Reichmann et al. (2008) for those cases in which unexpected downstream commercial applications appear. According to Reichmann et al. (2008), liability rules are true intellectual property rights, in the sense that they may confer an ex ante entitlement on the rights holder who makes the property available under certain conditions. At the same time, however, they are "take and pay" rules, in the sense that the rights holder cannot exclude qualifying users from making specified use, on condition that he or she pays the compensation required for such use.

5. Networking of BRCs

5.1. Networking initiatives

The existence of BRCs covering a broad geographic and political extension is certainly an important issue, but even more important is their coordination. Networking is a strategy for enhancing expertise, optimizing functionalities, reinforcing complementarities and raising a common voice to address specific problems that cannot be solved efficiently in an individual manner.

There are examples of consortia at different levels – national, regional and worldwide – that have been functioning for decades (Table 1) and many others that have been initiated more recently, particularly in East Asia, with much activity. Examples of the latter are the Asian Consortium for the Conservation and Sustainable Use of Microbial Resources (ACM) at the regional level, together with national initiatives in China, Korea, Thailand, Indonesia and The Philippines. By far the largest network is the World Federation for Culture Collections (WFCC), a Federation of the International Union of Microbiological Societies. It has an ongoing concern with all aspects of culture collection activity and, in particular, with encouragement of new initiatives and improvement in the standards of scientific services provided to the international user community.

As networks, all of them define objectives and establish task forces that usually focus on capacity building, information management, quality standards, enrichment and added value of accessible resources, support of endangered collections, etc.; in summary, they aim to provide better service to

Table 1
Examples of federations, societies and networks of BRCs with a long tradition. Data compiled as of November 2009 from web pages cited.

Name (acronym)	Web site	Ambit	Year founded	No. of collections
United Kingdom National Culture Collection (UKNCC)	http://www.ukncc.co.uk/	National (UK)	1947	10
Japan Society for Culture Collections (JSCC)	http://jscc-home.jp/	National (Japan)	1951	23
World Federation for Culture Collections (WFCC)	http://www.wfcc.info/	Worldwide	1970	561
European Culture Collections' Organisation (ECCO)	http://www.eccosite.org/	Regional (Europe)	1981	61
Belgian Coordinated Collections of Microorganisms (BCCM)	http://bccm.belspo.be/	National (Belgium)	1983	4

science and society by confronting, in a coordinated manner, the challenges of banking and curating biological resources. Their goals are fostered by concerted activities and projects, usually less extensive in participation and time, but very effective in serving as models for others and in providing a basis for future actions.

In Europe, since the 1980s, the European Commission has supported networking of culture collections through projects such as MINE (Microbial Information Network Europe), CABRI (Common Access to Microbial Resources and Information) and EBRCN (European BRCs Network). MINE stimulated the process of transition from individual hardcopy collection catalogues to electronic catalogues with compatible data formats in view of data integration. The CABRI project resulted in the on-line search of 28 linked catalogues of microorganisms, plasmids and cell lines, and also in the on-line consultation of many laboratory procedures used in collection work (www.cabri.org). EBRCN focussed on coordinated progress (www.ebrcn.net).

Among the recent initiatives to enhance the efficiency of BRCs by coordinating and driving activities to meet user needs at a global level, there are two current ones in which the authors of this review are involved: EMbaRC (www.embarc.eu) and GBRCN (www.gbrcn.org).

5.2. The European consortium of microbial resource centers, or EMbaRC

In November 2007, the EU launched a call for action under the Seventh Framework Program for Research Infrastructures. Among the lines of actions, there existed several so-called integrating activities via a targeted approach for responding to strategic research needs in thematic priority areas. One of them – INFRA-2008-1.1.2.9: BRCs – was clear motivation for a team of collections to work on an eligible project. Thus, EMbaRC was begun on the 1st of February 2009 and will last three years. It combines networking, joint research and training.

The EMbaRC project takes European collection networking to new heights of coordination and efficiency, providing new services and better access for users. Thus, EMbaRC aims to add value to BRCs by unifying methods for strain identification and validation of reference strains. It also intends to ensure consistent quality of all European collection resources by grouping together current best practices, tools and operational standards. To ensure compatibility in the quality of BRCs, the consortium aims to implement the current OECD (2007) best practice guidelines and emerging national standards for BRCs at the international level. Outreach and training activities will enable not only the EMbaRC consortium but all European collections to operate according to standards required to deliver products and services of comparable and consistent quality, thus meeting customer expectations both at present and in the future. Other networking elements are meant to give better access to authentic microorganisms and validated associated data using web technology and to provide a set of business models to increase self-sustainability of BRCs. Moreover, this project is creating the European node of the OECD-envisaged Global Biological Resource Center Network.

At the research level, EMbaRC aims to add value to the collections and related services for the benefit of all users. It will do this by developing improved techniques for strain and DNA storage to enable longer shelf-life. The project will also enable a high quality European microbial DNA bank Network, explore new methods for identification of species to ensure more accurate identification of bioresources and deliver high throughput screening for natural products of industrial interest.

In addition to networking (coordination) and research, the funding plan for integrating activities contains support for trans-national access to services and/or products of the BRCs. In the case of EmbaRC, a training and outreach program has been set up to provide grants to scientists working in a European Union member state or a country associated with FP7, to visit one of the EMbaRC BRCs and benefit from expert advice and advanced equipment during a stay which includes hands-on sessions.

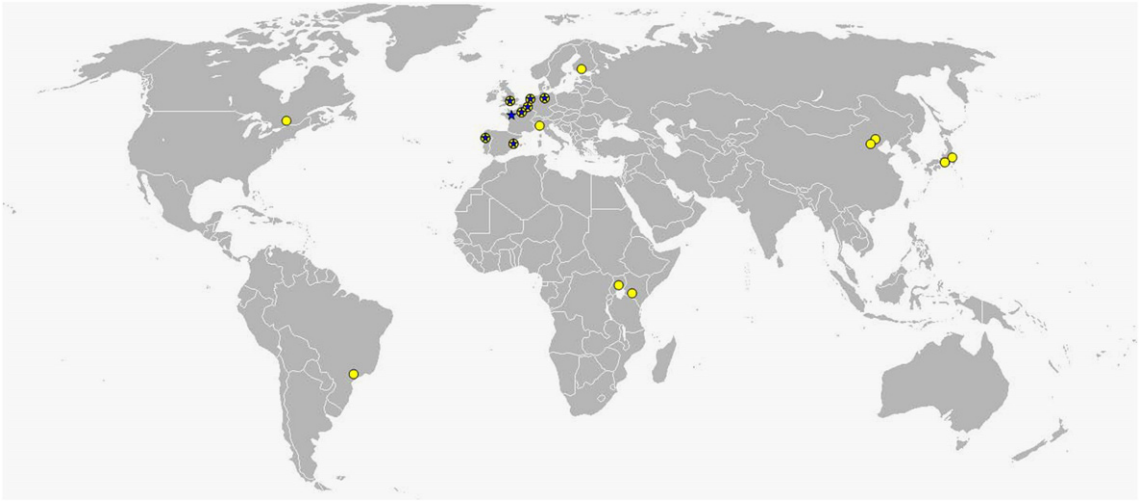

Fig. 1. Partners participating in GBRCN (circle), EMbaRC (star) or both (circle with star).

5.3. The global biological resource center network, or GBRCN

GBRCN is a demonstration project, following work in the OECD, to coordinate BRCs through a secretariat based in Braunschweig, Germany (supported by the German Federal Ministry of Research and Education). It began in November 2008 with the purpose of demonstrating the value of networking activities, developing common approaches and enhancing coverage of available organisms and information to meet user requirements.

A critical mass of microorganism domain (candidate) BRCs have been assembled together in a demonstration project to deliver a working model for a Global Network of BRCs as recommended in 2001 by the OECD (2001). As shown in Fig. 1, GBRCN gathers together 17 partners from 15 countries.

In between GBRCN and EMbaRC, there exist links and synergies. Some partners are common to both (Fig. 1) and, indeed some of their key members are also board members of ECCO and WFCC. There are also important differences, not only in the geographical ambit but also in funding and types of activities. Whereas GBRCN receives funding only for the secretariat and focuses on coordination, EMbaRC is funded to a large extent for its total costs and includes research and access in addition to networking.

6. Conclusion

In summary, depositing microbial research materials in public BRCs significantly contributes to the science (semi-) commons and maximizes the impact of prior knowledge. BRCs are professional infrastructures meant to preserve and authenticate the materials deposited and to provide open, independent, but regulated access to quality-controlled samples for legitimate end-users, taking into account all relevant regulations and stakeholders' rights.

BRCs increasingly join forces in scientific, technical, quality and management matters, to the benefit of the user community.

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