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MICROBIOLOGY
Perspective

MIRRI Promoting Quality Management Systems for Microbiology

Dunja Martin[1], Erko Stackebrandt[1] and David Smith[2]

[1]Leibniz-Institut DSMZ-Deutsche Sammlung von Mikroorganismen und Zellkulturen GmbH, Germany

[2]CABI, Egham, Surrey, TW20 9TY, United Kingdom

***Corresponding Author:** David Smith, CABI, Egham, Surrey, TW20 9TY, United Kingdom.

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Abstract

Biological Resource Centres have been defined as the next generation culture collections focussed on supplying high quality resources into biotechnology research and development. The Microbial Resources Research Infrastructure (MIRRI) is specifically working with the microbial domain Biological Resource Centres (mBRC) to coordinate their currently fragmented offer. In order to meet user quality demands, culture collections have established quality management systems initially based on World Federation for Culture Collections (WFCC) Guidelines for the establishment and operation of collections of micro-organisms. Once these principles are established they move on to implementing the requirements of the OECD best practice. Culture collections have in common the basic requirements to provide authentic, well preserved biological material that is reproducible in properties for the long-term with associated data to facilitate their use. Establishing quality management processes for authentication, preservation and data delivery would always be the first step, followed by other key activities introducing a culture of continual improvement. As with all such systems the ultimate beneficiary is the user so their requirements must always be taken into account. Such processes add administrative burden and are looked upon by culture collections as separate processes. MIRRI takes a different view; a quality management system must be built into the normal management processes of a BRC. The complex operational environment of the BRC must be addressed and an integrated overarching Policy Compliance Management System is needed. It can be argued that this is not just a concern for mBRCs but for microbiologists in general who maintain their own strains and must remain compliant in their work most recently impacted by implementation of the Nagoya Protocol on access and benefit sharing; implemented in Europe through EU Regulation No 511/2014. MIRRI is collaborating with the international community to develop this new integrated approach.

Keywords: *MIRRI; OECD; mBRCs; World Federation for Culture Collections*

Introduction

The provision of authentic high quality microorganisms for research, use as standards and in industrial applications in compliance with international conventions and regulations is essential for good science and reproducibility. Culture Collections have been offering a public service for over 100 years with recommended best practices having been around for at least four decades [1]. The Organisation for Economic Cooperation and Development (OECD) has recognized the Biological Resources Centre (BRC)as the next generation culture collection. They have placed the BRC centrally as an underpinning service to biotechnology [2]. Although the public service culture collections affiliated to the World Federation for Culture Collections (WFCC) have been following the WFCC guidelines [3] since their inception it was considered essential that a quality management system meeting today's standards was developed for BRCs [4]. The challenge of implementing these best practices and introducing third party assessment schemes was first taken up by the Global Biological Resource Centre Network (GBRCN - www.gbrcn.org) and now further developed at the regional level in Europe by the Microbial Resources Research Infrastructure (MIRRI – www.mirri.org). Furthermore the international community are looking to the International Standards Organisation (ISO) who has a technical committee, ISO/TC 276 Biotechnology, designing a set of standards for biotechnology impacting on the provision and use of living materials from biobanks (http://www.iso.org/iso/home/standards_development/list_of_iso_technical_committees/iso_technical_committee.htm?commid=4514241). Exchange of microorganisms is not solely between mBRCs or biobanks and

microbiologists, in fact most exchanges are simply bilateral between microbiologists. A study by Stackebrandt [5] demonstrated that less than 1% of the strains cited in a selection of European microbiology journals were in or originated from mBRCs. The need for legal clarity on use and the provenance of microorganisms means that in the future mBRCs and all microbiologists need to work more closely together to ensure legal compliance and good science.

There have been several initiatives to design quality management systems for microbial and cell culture collections [1]. The first community designed system was the WFCC Guidelines but national culture collection organizations also chose to design their own standards, for example the UK National Culture Collection (UKNCC) quality management system (www.ukncc.co.uk) and project consortia such as the Common Access to Biological Resources and Information (CABRI) guidelines (www.cabri.org). There are also general standards that can be applied to microbiology laboratories such as Good Laboratory Practice (GLP) and several International Standards Organization (ISO) norms e.g. ISO 17025, ISO Guide 34 and the ISO 9000 series. There are several publications on collection management and methodology that provide information on protocols and procedures [6-10] but it was considered that a set of minimum standards were required. The German Government through the Bundes ministerium für Bildung und Forschung (BMBF), the German Federal Ministry of Research and Education supported a small Secretariat to draw national efforts together in developing tools for the establishment of the GBRCN. Since the report of these activities [11] national and regional efforts have been initiated and by linking these together the process of the establishment of the GBRCN has begun. The US Culture Collection Network (USCCN) demonstrates an effort in North America to bring collections together on common goals (www.usccn.org). Whilst in Australia the Australian Microbial Resources Network (AMRiN) coordinates some activities of Australian Collections. In Asia the Asian Collections of Microorganisms have established the Asian BRC Network (www.abrcn.net). A basic requirement of any distributed network is common practice for operation and delivery of reproducible resources. Additionally, operation to international standards can improve the science based on such resources. The GBRCN is designed to first improve the quality management of BRCs and then, as a result, improve research and biotechnology through the authenticated material they provide. The regional efforts are moving at their own pace but sharing ideas, concepts and practice. In Europe, the pan-European ESFRI project 'MIRRI' recommends the adoption of quality management systems for its members [12]. The OECD best practice covers critical elements in the handling, storage, characterization and distribution of micro-organisms and cell cultures and the handling of associated information and sets the gold standard. However, it is not absolutely essential that all elements are introduced at one time and a process that sets a minimal level to ensure that resources are authentic, preserved in a stable condition for the long-term and that associated information is validated provides the ideal gateway to an environment of improvement and progress towards excellence. MIRRI look to introduce such a system.

Historically, many businesses, research institutions and culture collections have introduced ISO 9001 series (latest ISO9001:2008 with a new version scheduled for 2015) certification as a benchmark for quality in order to achieve preferred supplier status. This standard is based upon the concept of process management developing an evidence based system giving management system effectiveness through process performance measures and has developed with business needs over the years. Basically it works on the principle of systematic control of activities to ensure that the needs and expectations of customers are met. However, a comparison with OECD best practice demonstrates that ISO 9001: 2008does not adequately cover BRC operations thoroughly. It helps put in place good management systems but it does not address the output of culture collections or the competence to deliver cultures and associated services. In most cases, standards are designed for specific purposes in mind and need adjustment to address some of the specific operational requirements of a BRC. Some critical elements often not covered are:

1. Compliance with various legal requirements in association with the handling and shipping of biological materials.
2. The use and preparation of reagents, media and other supplies.
3. A strategic plan for BRC future sustainability in order to avoid the loss of biological resources; or
4. Data management and staff qualifications and competence. There are a number of ISO standards that go beyond the management of processes. ISO/IEC 17025, General requirements for the competence of testing and calibration laboratories is a standard used by testing and calibration laboratories. There are many commonalities with the ISO 9000 standard, but the former is more specific in requirements for competence. The ISO/IEC 17025 standard comprises five elements that are Scope, Normative References, Terms and

Definitions, Management Requirements and Technical Requirements. Management requirements are primarily related to the operation and effectiveness of the quality management system within the laboratory. Technical requirements include factors which determine the correctness and reliability of the tests and calibrations performed in laboratory. ISO/IEC 17025 is used to improve ability to consistently produce valid results. In contrast to ISO 9001:2008 it is accreditation and not a certification process. The accreditation is a formal recognition of a demonstration of competence. A number of culture collections employ ISO 17025 for specific activities or processes essential to their operations but seldom have all activities of the collection activities under this specific standard.. For example CABI is accredited for its molecular identification services for fungi and bacteria and its methods for sampling and testing mould resistance of materials.

Other standards have been adapted to a lesser degree such as ISO Guide 34, *General requirements for the competence of reference material producers*. However, this guide was written for reference material producers and used for the calibration of measuring equipment and for the evaluation or validation of measurement procedures such as pharmacopoeia standards and substances. Property values and their uncertainties are difficult to apply to living materials and many measurement principles cannot be utilized. Most BRCs do not work with reference material as defined for ISO Guide 34 but mostly with type strains which are references for the species but not reference material as defined for production.

This failure to address exactly the operation and needs of the BRC and its users has led many individual collections or collection communities to design their own systems. The French culture collection community worked with the French national organization for standardization, the Association Française de Normalisation (AFNOR), to develop the French standard NF S96-900 "Quality of biological resource centers (BRCs) – Management system of a BRC and quality of biological resources from human or micro-organism origin" [13]. The Brazilian network of collections worked with their accreditation bodies led by IMMETRO - National Institute of Metrology, Quality and Technology to design and publish the standard NIT-Dicla061 *Aplicaçõese Requisitos Adicionais Acreditação ABNT NBR ISO/IEC 17025 dos Centrosde Recursos Biológicos* for the accreditation of BRCs www.inmetro.gov.br/credenciamento/pdf/nit_dicla_061.pdf,

Whatever the authoritative document, standard or certification or accreditation process that is selected, a BRC quality management system must address several specific areas:

1. Organizational requirements
2. Equipment use, calibration, testing and maintenance records
3. Documentation management
4. Data management, processing and publication
5. Preparation of media and reagents
6. Accession of deposits to the BRC
7. Preservation and maintenance
8. Supply
9. Quality audit and quality review

Amongst the microorganism domain criteria set down by the OECD Best Practice Guidelines are recommendations on the following:

1. Staff-qualifications and training
2. Hygiene und biosafety
3. Equipment use, calibration, testing and maintenance records
4. Preparation of samples
5. Information provided with the biological material supplied

Essentially, the key actions in the transition to a BRC are implementing international operational standards to ensure the preservation and supply of authentic materials, employing the best practice in preservation and practices for the confirmation and validation of associated information. Additionally, BRCs must put in place mechanisms to keep pace with technological demands and perform research to add value to strain holdings. They need to work with national authorities and partners to implement national plans in the conservation of biodiversity, establish themselves as repositories for protection of intellectual property and be compliant with national

law, regulations, and policies. This requires more than a quality management system. The need to manage its roles in science, in an appropriate regulatory environment needs inbuilt management procedures that do not add unnecessary burden and be part of a BRCs normal business operations.

In particular, 2014 saw the enactment of the Nagoya Protocol on Access and Benefit Sharing (http://www.cbd.int/abs/text/) which addresses measures for accessing and sharing the benefits from use of genetic resources as an instrument of the Convention of Biological Diversity(http://www.biodiv.org/convention/articles.asp).The main premise of the Nagoya Protocol is:

A. to prevent the utilisation of genetic resources, or associated traditional knowledge, which were not accessed in accordance with the national access and benefit-sharing legislation or regulatory requirements of a Party to the Nagoya Protocol
B. to support the effective implementation of benefit-sharing commitments set out in mutually agreed terms between providers and users
C. to improve the conditions for legal certainty in connection with the utilisation of genetic resources and traditional knowledge

Users of biological and genetic resources have responsibilities in access and the fair and equitable utilisation of them. In Europe, the EU Regulation on ABS (EU) No 511/2014 (http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014R0511) was enacted simultaneously with the coming into force of the Nagoya Protocol and this will be followed by the European Member states putting in place implementing practices or instruments. In some countries this will be a balance between regulatory control and due diligence. Each country signatory to the CBD and the Nagoya Protocol will implement its own controls, ensuring compliance with the Protocol's requirements. All microbiologists, not just mBRCs, must align their practices in the conservation and use of genetic resources in their work to comply globally with the Nagoya Protocol on ABS requirements, as well as working within the spirit of the CBD and ensuring compliance with national laws and regulations of all countries within which they work [14].

To facilitate this MIRRI is establishing a common understanding on biological resource management that includes quality management systems utilising appropriate standards and best practice models. Providing authentic high quality resources presupposes that BRCs optimise their processes and continually improve the skills necessary to perform their duties. The goal is to optimise operation through permanent cyclic improvement processes. Improving the competence and assessing the expertise of an organization in its field of activity. Raising the reliability of biological resources and related information at least to a minimum quality level to meet the expectation of the stakeholders concerning the requirements for basic research, R&D or commercial production purposes is crucial. MIRRI will help MRCs adopt scientific/technical evaluation and improvement processes, to adapt to progress in science and business management in general. This requires the alignment of the demands and to reduce the discrepancies between collections.

MIRRI's common understanding on Quality Management System (QMS), appropriate standards and best practice models

To date the origin of the harmonized quality management system for BRCs has focussed on the biological material held and the BRCs range of services. The other most relevant factors determining the quality management of a BRC have concerned data sets, standard operating procedures and regulatory standards (Figure 1).

The conflict in finding an appropriate and harmonized quality management system on this basis is inherent to the system because it ignores the influence of parameters like collecting biodiversity, offering of various services, different funding strategies, different organizational structures, and different infrastructures within the organizations or different national regulations amongst the MIRRI member states. In addition the various and changing user demands as well as the need for establishing specialized BRCs are not covered by the system strategy so far. A common quality management system with shared procedures at the detailed level is not achievable given all these differences and thus would not be beneficial.

Additionally, external drivers have a strong impact on the definition of any future system of managing quality in BRCs. Besides globalization, rapid changes and progress in science, product development, technology, logistics, lifestyle, customer needs and demands together with increased regulatory requirements will lead to even greater needs for system-level thinking and practice in quality management rather than the fragmentary micro-management activities in this sector in the past. This managerial shift in quality management

applies even more to organizations in the biotechnology sector. Biotechnology is a an extremely agile, high-risk, fast-moving business environment dependent on talented scientists, structural knowledge application, visionary managers and clear-sighted investors, and that requires quite a different breed of supporting infrastructures. These infrastructures must be able to follow the demanding biotech community with its economical as well as political mandate and associated regulatory requirements. The research-infrastructure of MIRRI will provide a central access point for biotechnology to facilitate deposit of and access to the whole breadth of microbial diversity and related information as well as opportunities for knowledge-transfer and training. Thus quality management concepts and tools for MIRRI members must be more dynamic than many had realized and this also means that quality managers in BRCs have to adopt new approaches and techniques if they aim to sustain a universal influence on the competitiveness and success of their BRCs.

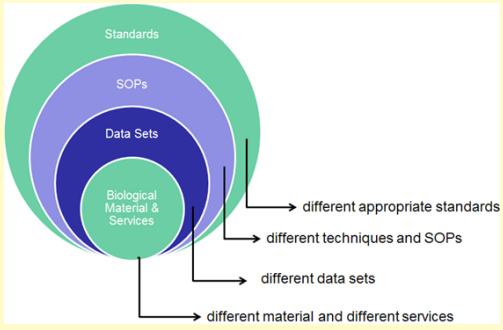

Figure 1: *Concept of the Task Setting.*

The main target of the BRCs in MIRRI is to ensure its individual mandate is in balance with the economic and scientific environment, as well as with the requirements of the MIRRI infrastructure. Thus the main goal can only be a system that fosters and stabilizes this balance.

Ultimately the challenge is to create a managerial strategy beyond standards as a consolidating system. MIRRI's definition of quality management is no longer restricted to the biological material, but to the organization's policy and the governance of different compliance needs, regardless of where they impact, be that IT-systems, social responsibility, laboratory processes or network membership criteria. The initial step is network driven by offering managerial solutions empowering a BRC to be a valuable partner in the MIRRI infrastructure. This essential shift incorporates the facts that BRCs are facing a growing regulatory environment, a higher complexity in their operations, seemingly limitless requirements by user communities and an increased focus on accountability. Hence a broad range of governance, risk, quality and compliance initiatives across the organization of a BRC seems to be necessary to cope with global development.

The new strategy counteracts the traditional management approach which uses a variety of mostly uncoordinated as well as independently planned and managed initiatives. Such thinking increases the overall risk for the organization. In addition, parallel compliance, quality and risk initiatives lead to duplication of effort and cause costs to spiral out of control. The new managerial strategy will master the situation accommodating the fact that governance, quality, risk, and compliance can be steered by similar processes. Through centrally managed control, definition, enforcement and monitoring a BRC has the ability to coordinate and integrate all these initiatives, that to date are managed independently and not mutual harmonized. Thus tackling the almost unscalable aforementioned challenges is within reach, if each BRC and MIRRI together, commit to this integrated approach of Quality Management and give way to a more eclectic "Policy Compliance Management System" (Figure 2).

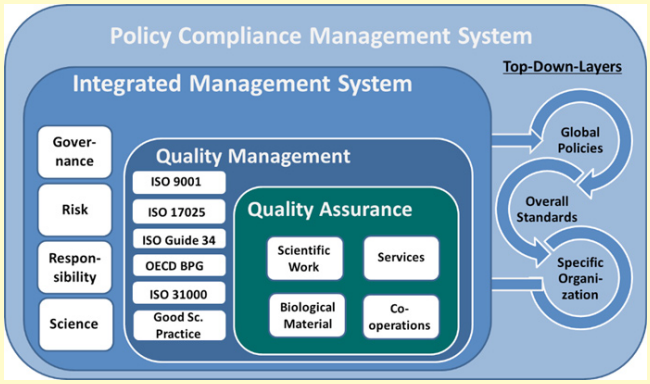

Figure 2: *Layered system structure Policy Compliance Management System.*

The layered system structure shows the *built-in*, rather than *controlled*, quality approach with a dedicated Quality Management mapping the compliance policy as the overarching priority in any effort for performance excellence.

The main steps to establish a common approach to quality management as an integrative part of the overarching Policy Compliance Management System, to develop and differentiate appropriate standards and to develop best practice models based on the transition that some BRCs have already made in their organizations is demonstrated in Figure 3.

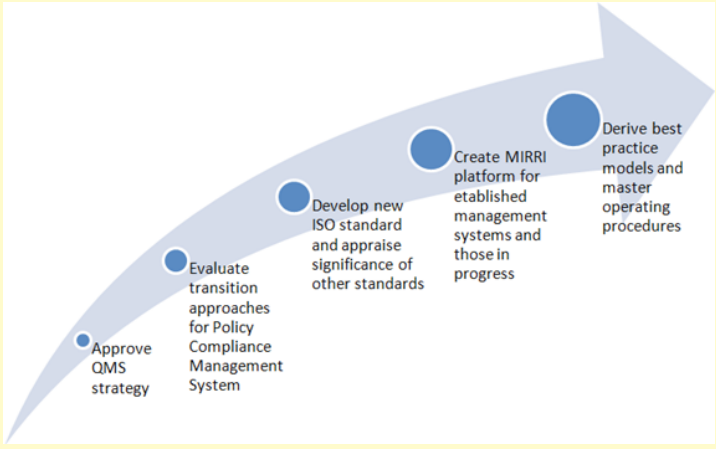

Figure 3: *The MIRRI Quality Management System agenda.*

As explained above the actual system of international standards, mainly created by ISO (International Organization for Standardization) and OECD (Organisation for Economic Co-operation and Development), is focussing the complementary aspects of management, technical skills, product conformity and process stability. The OECD Best Practice Guidelines for BRCs extend this system to the aspect of regulatory affairs. Each standard is specialised to enhance the compliance of an organisation to a single aspect (e.g. ISO 17025 which applies to technical skills). The view on the major overlap of suitable standards like ISO 9001, ISO 17025, ISO Guide 34, the French standard NF S96-900 and OECD Best Practice Guidelines for BRCs demonstrates that the OECD Best Practice Guidelines for BRCs covers a broad spectrum of the requirements delivered by other standards. The common is that the highest degree of coverage to support a biological resource centre in reaching a high compliance level in each aspect is given only by the OECD Best Practice Guidelines for BRCs.

But due to the deep linkage between BRCs and Biotechnology a strong, internationally acknowledged and far-reaching ISO standard is required to support the harmonization of core requirements and confidence building between the partners. ISO is the world's largest developer of voluntary, but highly recognized international standards giving state-of-the-art specifications for products, services and good practice and helping to make industry more efficient and effective. Developed through global consensus, ISO standards help to break down barriers to international trade. ISO is a network of 164 national standards bodies that make up the ISO membership and represent ISO in their country.

Since 2013 ISO/TC 276 "Biotechnology" has been coordinating the establishment of a new ISO standard in liaison with other technical committees to avoid conflicts and/or duplication. The founding meeting of international Technical Committee ISO/TC 276 took place in December 2013 in Berlin/Germany. The creation of the Technical Committee was preceded by a period of intensive preparation and different approaches to create appropriate standards or guidelines. The German DIN (Deutsches Institut für Normung) took the initiative and formally submitted a proposal for the creation of ISO/TC Biotechnology. In February 2013 this was approved, and DIN was entrusted with the secretariat.

The focus of ISO/TC 276 is to find standardization needs and gaps in the field of biotechnology. The scope of ISO/TC 276 is "Standardization in the field of biotechnology processes that includes the following topics: 1) terms and definitions; 2) biobanks and bio resources; 3) analytical methods; 4) bio processing; 5) data processing including annotation, analysis, validation, comparability and integration; 6) metrology.

One of the first standards is dedicated to Biobanks and lay down general principles for Biobanks within the next three years ISO/TC 276 Biotechnology will work closely with related committees in order to identify standardization needs and gaps, and collaborate with other organizations to avoid duplication and overlapping standardization activities. One of the first standards is dedicated to Biobanks and lay down General principles for Biobanks. Some MIRRI partners from France and Germany have taken an active role in defining this new standard. The new standard is expected to be launched in 2016. The impact on the compliance spectrum of a BRC is manifold and can mainly be identified as internal and external determinants.

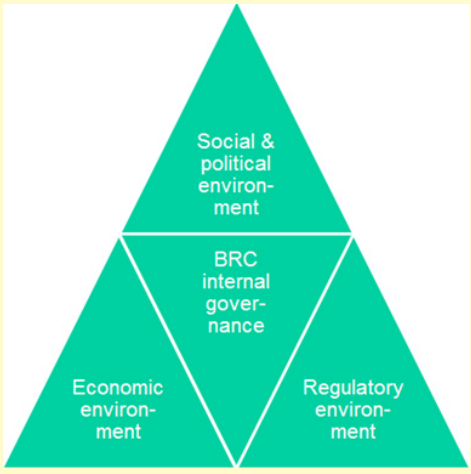

Figure 4: *Source of compliance determinants.*

The role of MIRRI will be to mirror the different compliance determinants, their impact and the transition of the associated BRCs in the different layers of the management system (Figure 4). MIRRI in addition has the ability to keep down costs for the BRCs by establishing a central core platform of experts, procedures and knowledge which will be accessible to members. The development of a knowledge and best practice base will lead to master instructions helping to deal with the different requirements. All information given by MIRRI is validated by the source BRC and thus applied management approaches.

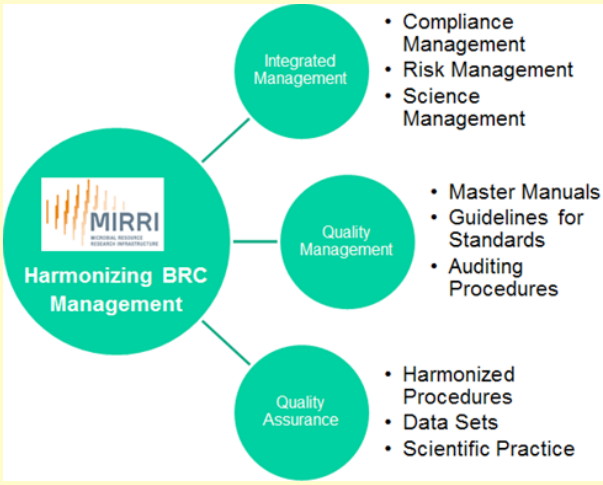

Figure 5: *Approach for a MIRRI Management System Platform.*

The generated knowledge and best practices will support emergent BRCs and create a benchmark system for already highly developed BRCs. The process of harmonizing procedures will mainly support the demand for comparable quality in producing high quality biological material and performing reliable services. Thus MIRRI serves as a provider hub to comparable and valuable on-site infrastructures mapping a shared system of compliance and quality (Figure 5).

Summary

mBRC have a role to provide high quality resources to facilitate innovation and discovery in biotechnology. It is imperative that the resources they supply meet the requirements of the user and are provided with legal certainty for use. As countries are deciding how to implement the Nagoya Protocol for Access and Benefit Sharing and in light of concerns of bio security the community of microbial resource centres is responding. The development of common quality management systems with the ethos of development of excellence is an integral part of MIRRI's activities. This complex operational environment must be addressed and an integrated overarching Policy Compliance Management System is needed for BRCs. It is not only the mBRCs that face this complex environment of legal requirements impacting on science but the scientists themselves. It is essential that we all work together to ensure the compliance of science.

Microbiologists require, in common with the ethos of public service collections, authentic, well preserved biological material that is reproducible in properties for the long-term with associated data to ensure good science practice. To ensure this, establishing quality management processes for authentication, preservation and data delivery is a key first step and to do this it is important to take advantage of the work already done in this respect. Given the developments described here it is recommended that:

A. Microbiologists contact their local or most relevant mBRC and form partnerships for compliant exchange of microbial resources and advice on quality management systems (see www.wdcm.org/for a list of collections worldwide)
B. Establish networks between microorganism users and providers built on existing microbiology societies and culture collection networks [1]
C. Build compliance mechanisms into daily routines but do not let the plethora of standards allow science to be a slave to them, learn from them and ensure the correct balance

Key actions in the transition of culture collections to an mBRC are:

1. Implementing international operational standards to provide:
    A. Authentic materials
    B. Best practice in preservation
    C. Confirmed, validated information
2. Keeping pace with technological demands
3. Performance of research and development – adding value to strains
4. Intergradation of the role of conservation of biodiversity, implementing national plans
5. Development as repositories for protection of intellectual property
6. Ensuring compliance with national law, regulations, and policies

Recommendations for membership of the proposed MIRRI and GBRCN require that mBRC status is assigned to those biological resource collections that:

1. Implement OECD best practice and join the GBRCN
2. Meet mandatory guidance laid down in the membership rules
3. Carry out research to add value to holdings

mBRCs shall comply with:

1. National legislation, regulations and policies concerning acquisition, conservation, utilisation, including the fair and equitable sharing of benefits and distribution of biological resources and data related thereto
2. The regulations of the relevant countries when moving biological materials across national boundaries

An mBRC will contribute to agreed network activities improving access and delivery of high quality biological materials and information. MIRRI is collaborating with the international community to develop and differentiate appropriate standards and to develop best practice. MIRRI is the place to come for advice on implementing microbial resource management standards and for the microorganisms and expertise to support research and development [16,17].

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Bibliography

1. Smith D. "Culture Collections". *Advances in Applied Microbiology* 79 (2012): 73-118.
2. OECD. "Biological Resource Centers: Underpinning the future of life sciences and biotechnology". *OECD Publications, Paris, France* 66 (2001).
3. Anon. "The WFCC Guidelines for the Establishment and Operation of Culture Collections" (2010).
4. OECD. "Best Practice Guidelines for Biological Resource Centers (2007).
5. Stackebrandt E. "Diversification and focusing: strategies of microbial culture collections". *Trends in Microbiology* 18 (2010): 283-287.
6. Hawksworth DL and Kirsop B. "Living Resources for Biotechnology". *Cambridge University Press, UK* (1988).
7. Kirsop BE and Kurtzman CP. "Living Resources for Biotechnology: Yeasts". *Cambridge, Cambridge University Press, UK* (1988): 234.
8. Kirsop BE and Doyle A. "Maintenance of Microorganisms and Cultured Cells: A Manual of Laboratory Methods". *London: Academic Press* (1991): 308.
9. Smith D and Onions AHS. "The Preservation and Maintenance of Living Fungi". Second edition. IMI Technical Handbooks No. 2 (1994). CAB International, Wallingford, UK.

10. Smith D., *et al*. "The UKNCC Biological Resource: Properties, Maintenance and Management". 382 pp. UKNCC Secretariat, Egham, Surrey, UK (2001): ISBN 0954028503
11. Fritze D., *et al.* "Third intermediate report on the GBRCN Demonstration Project". Germany: GBRCN Secretariat (2010): ISBN 978-3-00-031458-2
12. Smith D. "Biological Resource Research Infrastructures to drive innovation in microbiology". *Microbe* 6.11 (2011): 482.
13. AFNOR. French Standard NF S96-900 "Quality of biological resource centers (BRCs) - Management system of a BRC and quality of biological resources from human or micro-organism origin" (2008).
14. Verkley G. "How will the Nagoya Protocol affect our daily work?" *International Mycological Association Fungus* 6.1 (2015): 3-5.
15. Smith D and Ryan MJ. "The impact of OECD best practice on the validation of cryopreservation techniques for microorganisms". *Cryoletters* 29 (2008): 63-72.
16. Christine Rohde., *et al*. "Code of Conduct on Biosecurity for Biological Resource Centres: procedural implementation". *International Journal of Systematic and Evolutionary Microbiology* 63 (2013): 2374-2382.
17. Smith D Fritze D and Stackebrandt E. "Public Service Collections and Biological Resource Centres of Microorganisms". In: The Prokaryotes: Prokaryotic Biology and Symbiotic Associations. Editor-in-chief: Rosenberg Eugene DeLong EF., *et al*. (Eds.). 4th edn. (2013): 267-304.

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