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The Convention on Biological Diversity and Microbial Diversity: Issues of Interest to the Microbial Scientist and Microbial Culture Collections

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SUMMARY

The Convention on Biological Diversity is very relevant to the work of microbial scientists and microbial culture collections. It may provide them with undefined and unexplored new opportunities to explore microbial diversity at the genetic, taxonomic and ecosystem level.

This paper provides a brief overview of the Convention as (1) a legal document and (2) an institution. In so doing, it highlights some areas where the Convention may intersect with the work of microbial scientists and microbial culture collections. Suggestions on how microbial scientists and culture collections may be able to shape the Convention's effective implementation to their benefit is also made. In the process, the paper attempts to answer three questions:

a. How will the Convention on Biological Diversity affect the work of microbial scientists and microbial culture collections?
b. Will additional funding be available?
c. How effective is the Convention likely to be?

Because the Convention is new, it is not able to provide hard and fast answers to these questions but, as might be expected with such a new instrument, the situation is rapidly

evolving. Therefore, it is hoped that this paper will promote greater appreciation of the Convention and provoke microbial scientists and culture collections to take part in the Convention's application to microbial diversity.

INTRODUCTION

Microbial scientists work literally on biodiversity's frontier as, in many cases, micro-organisms ^2 are the biological interface with the earth's physical and chemical environments. Though we do not have a full understanding of all the roles they play in any particular ecosystem (Stackebrandt, 1994), micro- organisms are viewed as essential to all life on earth because of the key ecosystem processes they orchestrate. For example, micro-organisms have key roles in mineralization, organic matter production, geochemistry and nitrogen availability (Stackebrandt, 1994; Mooney *et al*., 1995). In addition, in mutualistic associations micro-organisms provide the biological interface with the physical and chemical environment that enables some higher organisms to survive whether in a tropical or temperate forest, a farmer's field or around a hydrothermal vent on the sea-bed thousands of metres below the ocean's surface. Furthermore, micro-organisms are indispensable components of the digestive tracts of vertebrates and invertebrates.

Even though only approximately 150,000 microbial species have been described (Sly, 1994) representing an estimated 5 percent or less of the world's microbial species (Mooney *et al*., 1995), it can be confidently said that microbial diversity dwarfs that of macro-organisms (Holmes, 1996). Micro-organisms occupy all niches where life is thermodynamically possible (Mooney *et al*., 1995), reflecting the greatest breadth of genetic diversity of biological groups (Sly, 1994). This genetic diversity provides micro-organisms with a wide range of physiological and biochemical attributes (Stackebrandt, 1994).

With the application of molecular biology, and new as well as traditional techniques for isolating and growing micro-organisms, microbiology stands poised at the brink of a new era of exploration, discovery and description of microbial diversity, its role in ecosystem structure and functioning, the threats it faces and its practical applications in human endeavours such as biotechnology. The new microbial era - and the breaching of what some have described as a new biological frontier (Holmes, 1996) - is dawning coincidentally just at the time when over 140 States are beginning to implement a major new international conservation agreement. The Convention on Biological Diversity has often been described as "a new contract for a new era", an era characterized by heightened scientific and political awareness of the global loss of biological diversity.

The primary message of this paper is that the Convention on Biological Diversity (CBD) is very relevant to the work of all microbial scientists, as well as microbial culture collections (MCCs). This is so even though the terms "micro-organism" and "microbial" each only appear once in its text and are not defined. If drawn on and used creatively, the Convention may provide microbial scientists and MCCs who participate in its implementation at the global and national levels with a host of as yet undefined and unexplored new opportunities to explore microbial diversity at the genetic, taxonomic and ecosystem levels.

This paper will provide a brief overview of the Convention as (1) a legal document and as (2) an institution. In so doing, it will highlight some areas where the Convention may intersect with the work of microbial scientists and MCCs. Suggestions on how microbial scientists and MCCs may be able to shape the Convention's effective implementation to their benefit will also be made. In the process, the paper will attempt to answer three questions:

. How will the Convention on Biological Diversity affect the work of microbial scientists and MCCs?

. Will additional funding be available?

. How effective is the Convention likely to be?

Because the Convention is so new, it will not be able to provide any hard and fast answers to these questions immediately. But, as might be expected with such a new instrument, the situation is rapidly evolving. Therefore, at the very least, it is hoped that this paper will promote a greater appreciation of the Convention on Biological Diversity and provoke microbial scientists and MCCs to take part in the Convention's application to microbial diversity.

ORIGIN AND HISTORY

The need for a global convention on biological diversity was recognized by international experts as early as 1975, well before intergovernmental negotiations took place under the guidance of the United Nations Environment Programme (UNEP). But it was not until the mid-1980s that serious work towards such a treaty began.

Following recommendations by its General Assemblies in 1984 and 1987 the World Conservation Union (IUCN) began exploring the possibilities. Between 1984 and 1989, the IUCN Commission on Environmental Law, in conjunction with the Joint IUCN/WWF Plant Advisory Group, produced successive draft articles which could be incorporated into a draft treaty. By 1987, the UNEP Governing Council recognized the need to streamline international efforts to protect biological diversity.

This derived in part from the piecemeal treatment of biodiversity in treaty law at the global level and the perception that there was a need to address biological diversity comprehensively. Though at the time there were many international, especially regional agreements, in existence dealing with different aspects or components of biological diversity, there were only four major global instruments:

. The Convention on Wetlands of International Importance as Waterfowl Habitat (Ramsar, 1971);

. The Convention Concerning the Protection of the World Cultural and Natural Heritage (Paris, 1972);

. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Washington, 1973); and

. The Convention on the Conservation of Migratory Species of Wild Animals (Bonn, 1979).

By 1990, the need for a convention on biological diversity was generally recognized in both scientific and political circles and discussions shifted to the scope of such a treaty.

Developed countries, notably the United States, supported a conservation-oriented treaty. But many other countries, primarily developing, did not want to make the convention just another nature conservation treaty. Instead they succeeded in broadening the scope of the discussions to include all aspects of biodiversity, in particular:

. *in-situ* and *ex-situ* conservation of wild *and* domesticated species;

. sustainable use of biological resources;

. access to genetic resources and the equitable sharing of benefits derived from their use;

. access to relevant technologies, including biotechnology;

. the biosafety of living modified organisms; and

. new and additional financial resources for developing countries.

Formal negotiations began in 1991 and the Convention was adopted in Nairobi on 22 May 1992. It was later opened for signature at the United Nations Conference on Environment and Development (UNCED), in Rio, on 5 June 1992. The convention entered into force only 18 months later on 29 December 1993.

THE CONVENTION AS A LEGAL DOCUMENT

At its most basic, a treaty is a collection of rights and obligations between its Parties. In the case of the Convention on Biological Diversity, its Parties are States and regional economic integration organizations (REIOs) such as the European Union. By ratifying the treaty, its signatories agreed to be bound by its obligations and are entitled to its benefits. Presently, over 140 States and the European Community are Parties to the Convention on Biological Diversity.

A. The Character of the Convention

The Convention on Biological Diversity comprises a comprehensive set of far-reaching obligations for each Party to address biological diversity at the genetic, taxonomic and ecosystem levels. Its primary objectives are the:

. conservation of biological diversity;

. sustainable use of its components; and

. fair and equitable sharing of the benefits derived from the use of genetic resources (genetic material) (article 1).

A unique characteristic of the Convention is that its provisions are mostly expressed as overall goals and policies, rather than precisely defined obligations. Decision-making at the national level is emphasized in lieu of treaty derived lists of internationally important biogeographical sites or species to protect.

Participatory biodiversity strategic planning processes will be created at the national level to facilitate national action according to a Party's particular circumstances (article 6). The Convention articles set out the minimum goals and policies to be considered in an action-oriented national strategic planning process. They provide the basis for Parties to compare and match their own policies and laws with regard to:

. *in-situ* conservation (article 8);

. *ex-situ* conservation (article 9);

. sustainable use (article 10);

. environmental impact assessment (article 14);

. research and training (article 12);

. public education and awareness (article 13);

. access to genetic resources (article 15);

. access to and transfer of technology (article 16);

. information exchange (article 17);

. scientific and technical cooperation (article 18); and

. financing (article 20).

B. Fundamental Principles of the Convention

A number of fundamental principles provide the Convention's foundation and can be used to guide each Party's action.

First, the conservation of biological diversity is the common concern of humankind. "Common concern" implies a common basis for the international community to act to conserve biological diversity, even if the components of biological diversity exist within national jurisdiction, because of biological diversity's importance to all life on earth, including humans.

Second, States have sovereign rights (but not necessarily property rights which are defined by national law) over natural resources found within their jurisdiction. This principle is reiterated in various forms at least three times within the Convention:

. States have sovereign rights over their own biological resources (Preamble);

. States have the sovereign right to exploit their natural resources pursuant to their own environmental policies (article 3);

. States, pursuant to their sovereign rights, have the authority to determine access to genetic resources (article 15).

Third, States are responsible for conserving their biological diversity and for using biological resources in a sustainable manner. Sovereign rights of States bring with them responsibilities. This principle links the sovereign rights of States to the common concern that all of humanity has for the conservation of biological diversity.

Fourth, the Convention espouses both a preventive approach and a precautionary approach to the loss of biological diversity. The aim of the preventive approach is to anticipate, prevent and attack the causes of biodiversity loss. In other words, the Convention espouses that it is preferable to take a proactive approach to biodiversity loss instead of a reactive approach. The aim of the precautionary approach is to prevent the use of scientific uncertainty as a reason for postponing measures to avoid or minimize threats to biological diversity.

C. Strategies and Integration

The Convention on Biological Diversity was developed with national priorities in mind. Therefore, its implementation is country-driven in nature.

To accomplish this, article 6 requires Parties to develop biodiversity strategies and action plans and integrate conservation and sustainable use into relevant governmental plans, programmes and policies. These are perhaps the most important provisions in the Convention.

Article 6 is premised on the view that biodiversity loss in modern times - whether intended or not ^3 - is the consequence of certain human activities (preambular paragraph 5). In other words, stemming the loss of biodiversity is really a matter of managing human activities.

Biodiversity strategies are the mechanisms through which countries can organize and implement their approaches to biological diversity's conservation and its components' sustainable use. Consequently, these documents will set- out the research, conservation, capacity-building and funding priorities of the country.

Biodiversity strategies are also ideal mechanisms for heightening public awareness of the biodiversity issue and encouraging public participation in its conservation. This is because biodiversity conservation is a complex and multi-faceted task which, because of it roots in socio-economics, must involve government, capital (industry and private business) and civil society (including private citizens and scientists) (Kloppenburg and Gonzales, 1994).

As a result, the process of developing a strategy is just as important as the document itself. Only through a participatory process can the necessary constituency be developed to identify relevant biodiversity-related issues, propose action needed to resolve them and carry out and follow through on the actions proposed in the strategy document. Therefore, developing a biological diversity strategy could be an ideal opportunity to build the political awareness and will to stem the loss of biological diversity.

The national biodiversity planning process should treat microbial diversity issues at the genetic, taxonomic and ecosystem levels in the context of those aspects of the Convention which are most applicable to microbial diversity - whether in terms of research, conservation, capacity-building or funding. As process participants or as consultants, the knowledge and skills of microbial scientists and MCCs are absolutely critical to the national biodiversity planning process if microbial diversity is to be adequately treated as a sectoral issue, as well as a cross-sectoral in relation to other issues. In short, it is microbial scientists and MCCs which can ensure that microbial diversity gets treated in a country's national biodiversity strategic plan at all.

D. Identification and Monitoring

Perhaps one of the most interesting Convention articles for microbiologists and MCCs is article 7 (Identification and Monitoring). Of course, microbial scientists and MCCs have been identifying and monitoring microbial diversity well before the Convention entered into force.

But microbial scientists, perhaps more than other life scientists, have been faced with a host of obstacles in identifying and monitoring the components of microbial diversity. Problems such as minute cell sizes, seasonality, morphology changes, substrate or host dependency and recalcitrance, for example, have impeded understanding of the true extent of microbial diversity and the identification and functional attributes of organisms even in small environmental samples (Stackebrandt, 1994; Mooney *et al*, 1995).

While the Convention on Biological Diversity probably will not help microbiologists overcome these traditional technical problems directly, it can provide the international legal justification and global policy framework for its Parties to support microbial work at the national level which focuses on:

. identifying and monitoring the components of microbial diversity (article 7(a) and (b));

. identifying and monitoring the processes and activities which have or are likely to have significant adverse effect on microbial diversity (article 7(c)); and

. organizing the data collected (article 7(d)).

Therefore, the implementation of article 7 may have several implications for the work of microbial scientists and MCCs.

First, the text makes clear that identification and monitoring shall be primarily for:

. *in-situ* conservation;

. *ex-situ* conservation; and

. sustainable use of the components of biological diversity.

This is a very strong message that identification and monitoring are to be tools for action and not simply ends in themselves. A good example of this "application- oriented approach" is that the Convention's Conference of Parties (COP) sought the advice of the Convention's Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) on "adopting a more practical direction [for] taxonomy [by] linking [it] to bio-prospecting and ecological research on conservation and sustainable use of biological diversity and its components" (Conference of the Parties to the Convention on Biological Diversity (hereinafter COP), 1995a).

Another example is the Convention's link between the identification of processes and activities which adversely affect biodiversity (article 7(c)) and regulating or managing the processes and activities so identified (article 8(l)). In addition, among other applications, identification and monitoring will be necessary for:

. biodiversity strategies and action plans (article 6(a));

. integrating conservation and sustainable use into government plans, programmes or policies (article 6(b));

. environmental impact assessment (articles 14(a) and (b)), as well as regulating, managing or controlling the risks associated with the use and release of

living modified organisms (LMOs) (article 8(g)); and

. negotiating agreements for bioprospecting or access to genetic resources (article 15).

The second implication of article 7 is that it does not require full inventories to be prepared of all components of biological diversity. The Convention's drafters realized that while biodiversity loss is accelerating the capacity of all Parties to undertake identification and monitoring is limited for a number of reasons.

Therefore, in part to help Parties and scientists better prioritize scarce financial, technical and human resources, Annex I of the Convention provides an indicative list of priority components of biological diversity organized at the ecosystem, taxonomic and genomic levels which should be identified and monitored. These are characterized in terms of distinctiveness, richness, representativeness, economic, cultural or scientific importance or potential and the extent to which they are threatened.

For example, at the ecosystem level, those ecosystems which harbour endemic species or are representative, unique or associated with key evolutionary or other biological processes are highlighted. Species or communities which are threatened or important for research into conservation and sustainable use of biological diversity are among the species level priorities. The Convention is perhaps weakest at the genomic level where priorities are limited to *described* genomes and genes of social, scientific or economic importance.

These and the other Appendix I priorities may be reflected in a country's national biodiversity strategy. Consequently, tailoring microbial identification and monitoring to focus on these priority areas could be considered.

Third, the emphasis on monitoring and data organization means microbial scientists and MCCs should consider making their data more accessible and comparable not only for their own use and the use of others in their field, but also for the policy-making process, both in terms of physical access to databases as well as in terms of presenting data in a manner useful to the policy maker. The fundamental point is that policy makers, managers, educators and the public at large do not need data *per se*, but rather information derived from the data collected.

Microbial scientists and MCCs, or their professional organizations could assist Parties to develop the capacity to analyze, evaluate and disseminate new and existing information related to microbial diversity in a usable form. This information could then feed into decision-making processes to support actions designed specifically to conserve or sustainably use microbial diversity, where relevant, or other aspects of biological diversity.

For example, information on micro-organisms restricted to particular environments could be used to develop measures designed to protect the habitat of these communities from threatening human development activities. In addition, in spite of the large knowledge gaps about microbial diversity, knowledge is accumulating on the importance of functional groups in microbially mediated ecosystem processes (Mooney *et al*., 1995). The importance of these processes, their sensitivity to human mediated changes in biological diversity and what microbial processes may replace them could be factored into a proposed development project's environmental impact assessment to more accurately assess the overall degree of threat to biological diversity or how the project could contribute to other environmental threats such as climate change. Finally, information generated from microbial identification and monitoring activities could be used as the basis for conserving or sustainably using other aspects of biological diversity.

Fourth, with the Convention's emphasis on national priorities, it will be very important for national identification and monitoring efforts to be effectively linked with existing programmes either nationally or globally. This will maximize the efficient use of resources and avoid duplication of efforts.

Identification and monitoring is on the Medium Term Work Programme of the Convention's Conference of Parties for 1996. Consequently, microbial scientists and MCCs and their professional organizations could consider what aspects of microbial identification and monitoring they would like the COP to address, or whether it would be best to have the COP look at microbial identification and monitoring in a comprehensive treatment of microbial diversity issues.

E. Research and Training

Because of its focus on research and training, and therefore capacity building, article 12 is directly relevant to almost every substantive obligation in the Convention. Consequently, it is truly a Convention cornerstone and extremely relevant to many activities involving microbial diversity. While emphasizing the needs of developing countries, it addresses:

. human capacity building through scientific and technical training (article 12(a));

. research contributing to conservation and sustainable use (article 12(b)); and

. international cooperation to use biodiversity related research to develop methods to conserve and sustainably use biological resources.

Perhaps this article's most important aspect is its emphasis on human capacity building. This has been further emphasized by the COP.

For example, in a recent decision the COP asked the Convention's SBSTTA to address the issue of the general lack of taxonomists needed to implement the Convention nationally and recommend to the COP ways and means to overcome the problem (COP, 1995a). This is particularly relevant to microbial scientists and MCCs because a limited number of trained terrestrial and marine microbial scientists^1 has generally hampered microbial work in the past, and the situation appears to be getting worse. A concerted effort by microbial scientists, MCCs and their professional organizations could be orchestrated to use the Convention as a political platform to propose, justify and implement global and national actions to ameliorate the situation and thereby provide support for microbial diversity issues at a very fundamental level.

Another important point to take away from analysing article 12 is the realization that biodiversity conservation and the sustainable use of its components involves the interaction of ecological, economic, social and political processes. In other words, biodiversity conservation is a cross-sectoral issue that demands an inter-disciplinary approach to tailor appropriate solutions to stem its loss. In fact, inter-disciplinary approaches are a prerequisite to the "ecosystem approach" which the COP has decided should be the framework for action (COP, 1995a).

Therefore, article 12 may have several implications for microbial scientists and MCCs. For example, the cross- sectoral nature of biodiversity conservation and sustainable use and the needs of policy makers could provide the basis for microbial scientists and MCCs to enter into interdisciplinary research areas involving non-microbial scientists.

In addition, because research takes place within a specific socio-political setting, sustained research programmes involving microbial diversity will require support from the general public, political leaders and even biological resources managers all of whom may have little understanding of the subject area. When national budgets are tight, microbial scientists and MCCs will need to develop a constituency to undertake the projects they see as important. This could be accomplished by:

. linking activities to the Convention's implementation and, in particular, referring to the Convention in research and funding proposals, especially if the donor or target country is a Party to the Convention;

. building alliances and undertaking joint or interdisciplinary research with non-microbial scientists working on biological diversity issues;

. tailoring research programmes and results to the needs of biological resource managers and policy- makers;

. effectively communicating the importance of research proposals and results to the general public and political leaders through the popular press or by making public presentations; and

. ensuring that the knowledge created is accessible and freely disseminated in the public domain.

F. Public Education and Awareness

Article 13 (Public Education and Awareness) is another cornerstone of the Convention. The public's general lack of awareness of biodiversity's importance - its relevance to every day life, the benefits from its use and the consequences of its loss - is the single most important constraint which needs to be overcome if we are to succeed at stemming the loss of biodiversity. The typical view has been that developing countries in particular need to emphasize education and awareness activities because of their traditionally more subsistence based economies. However, it seems more urgent to target developed country societies primarily because their technological and economic dependencies, premised on externalising the costs of natural resource overconsumption, have left the entire world more vulnerable to global environmental changes such as the loss of biological diversity.

In fact, technology has enabled industrialized countries to seemingly sever the link between humans and the biosphere, lulling societies into a false sense of security that they can simultaneously live both beyond the limits of sustainability while destroying biological diversity.

In effect, biological diversity needs to be popularized to re-connect people and re-establish some level of appreciation of what life on earth depends upon. This could start with microbial diversity. Microbial diversity needs to be popularized, doing it in a way which makes this very complex, intangible and largely invisible subject area something that even politicians can relate to. Because micro-organisms cannot be readily seen, the difficulties of raising public awareness may be enormous, especially since conservationists have generally had a difficult time convincing policy makers that the more visible manifestations of terrestrial and marine biodiversity are important ecologically. Other factors such as the stigma of micro-organisms in the context of human health may also have to be overcome. The key roles microbes play in all aspects of human life may have to be emphasized, while linking microbial diversity to things that capture peoples' imagination.

For example, few could not feel wonderment over the fantastic discoveries which have been made by some microbial scientists in recent years: discoveries of micro-organisms and associated macro-organisms living in bizarre extreme environments such as hydrothermal vents; or the possibilities for microbial life in the sub- glacial lakes of Antarctica (Noble Wilford, 1996); or even the speculation that micro-organisms might exist extra-terrestrially on Mars (Jakosky, 1996). In some respects, then, the extremophiles could be made into the "charismatic micro-organisms" of the microbial world providing an ideal opportunity to educate and enthuse people about microbial diversity and perhaps draw new researchers into the field. The biotechnology industry certainly is excited by the commercial potential of extremophiles and their biochemistry (Gross, 1996; Glowka, 1995; Broad, 1993).

With regard to education, there is undoubtedly a need to develop more holistic formal university level programmes dealing with microbial diversity and environmental microbiology both in developed and developing countries. In addition, programmes implemented at the primary and secondary school levels could reach many young people at a most receptive age if care is taken to develop close ties with educators, create appropriate curricula and evaluate curricula implemented.

Furthermore, emphasis could also be placed on informal education, that which takes place outside the classroom. Informal education achieves its results primarily through the use of different media such as radio TV, film, newspapers and books. While important in its own right, informal education may be useful in supplementing more formal educational experiences. Informal education may be especially useful in raising awareness about microbial diversity as it can be targeted to different sectors of society, for example, the government or private sectors, adults or children or even males and females.

At very least, microbial scientists should be encouraged to write more for the popular media. Microbial scientists and MCCs should also explore developing educational partnerships with zoos, botanic gardens, aquaria, natural history museums as well as national parks and other protected areas. All of these organizations have unique facilities which are compatible with educational goals and are particularly well-suited to educating diverse groups of people. All work in areas which directly or indirectly intersects with microbial diversity issues.

Finally, public education and awareness is closely related to speaking out or advocating particular points of view. In this regard microbial scientists, MCCs or their professional organizations could provide scientific support to advocacy-oriented non-governmental organizations (NGOs). Or they could in effect become "biopoliticians" by becoming more advocacy-oriented about microbial diversity issues whether at the national level or in international fora such as the Convention on Biological Diversity.

G. Conservation and Sustainable Use Measures

As one might expect from its objectives, the Convention's conservation and sustainable use provisions form its heart. In fact, almost all of the Convention's provisions have as their focal point conservation of biological diversity and the sustainable use of its components.

1. Conservation Measures

The Convention has provisions dealing with *in-situ* and *ex-situ* conservation. The *ex-situ* measures of article 9 are to complement *in-situ* measures and include:

. conserving *ex-situ* the components of biological diversity preferably in the country of origin;

. establishing and maintaining *ex-situ* conservation facilities preferably in the country of origin;

. undertaking threatened species recovery, rehabilitation and reintroduction; and

. cooperation between Parties, especially with developing country Parties.

Ex-situ conservation is emphasized as a complement to *in-situ* conservation.

But while it appears more or less straightforward to apply the Convention's *ex-situ* conservation provisions in the context of micro-organisms (WFCC, 1994; IUMS and IUBS, 1994) with the exception of the introduction of living modified micro-organisms (article 8(g)) or alien micro-organisms (article 8(h)), application of the Convention's *in-situ* conservation provisions is not as immediately apparent. This is so given the nature of microbial diversity (noted in Section D) as well as what seems to be a natural tendency to generally think of *in-situ* conservation only in terms of terrestrial and marine macro-organisms and their habitats.

In general, the Convention's *in-situ* conservation obligations call for a broad range of measures such as establishing national protected area systems, rehabilitating degraded ecosystems, threatened species recovery as well as natural habitat protection and maintaining viable species populations in natural surroundings. In all, the Convention's *in-situ* measures can be broken down into 3 broad categories dealing with:

. ecosystem-based measures;

. species-based measures; and

. measures related to processes and activities threatening biological diversity (alien species and living modified organisms released into the environment are specifically mentioned).

These measures are intimately related to identification and monitoring activities (article 7), research and training (article 12), technical and scientific cooperation (article 18) and financial resources (article 20).

Some commentators cite the "ubiquity of micro-organisms" as the basis for dismissing *in-situ* conservation measures directed broadly towards micro-organisms (Holmes, 1996). Others note that *in-situ* measures should not be overlooked. For one thing, many micro-organisms are not ubiquitous at all (Mooney *et al*., 1995). *In-situ* conservation may also be important because micro-organisms have wide, environmentally determined genetic diversity, environmental change, including degradation, influences microbial occurrence and population dynamics and pristine or near pristine areas protected from human activity are needed to maintain and observe microbial evolutionary processes (Sly, 1994). In addition, it is unclear whether ecosystem rehabilitation, a goal of article 8(f), will contribute to maintaining microbial diversity (IUMS and IUBS, 1994).

It can generally be assumed that measures to protect ecosystems and macro-organisms will generally benefit the microbial diversity of these areas and the micro- organisms associated with a particular macro-organism. Ideally, microbial scientists should be involved, therefore, in the early stages of planning for ecosystem and species-based conservation measures, especially where these measures are to be taken with regard to areas of endemism and endemic species. National biodiversity planning processes may provide unique opportunities for microbial scientists and MCCs to get more involved with *in-situ* conservation policies and planning which for one reason or another have not historically involved microbial diversity.

But microbial scientists will also need to become involved at the international and national levels to ascertain how article 8 can be best applied to microbial diversity itself, based on current knowledge and understanding of the level of human threat, as well as the application of the preventative and precautionary principles described earlier. Among other things, this could have important ramifications for tailoring existing and future species and ecosystem-based legislation to protect particular microbial species, habitats and microbially mediated ecosystem processes, an area which is almost completely neglected in existing nature conservation legislation.^5

Action may be immediately warranted in a limited number of instances where human activities threaten:

. a micro-organism or a microbial community endemic to a particular environment (extremophiles such as those in geothermal pools may be a good example); or

. one or a few micro-organisms responsible for a microbially mediated ecosystem process or a particular mutualistic interaction with a species of macro-organism (Mooney *et al*., 1995).

A more difficult situation to judge may be where a micro- organism is threatened as a result of the conservation status of a macro-organism it has a close mutualistic relationship with, since the extinction of the macro- organism will result in the micro-organism's extinction as well. Working at the global level or within a national biodiversity planning process, microbial scientists and MCCs could work together with other biological resource managers to identify situations where *in-situ* conservation of micro-organisms or microbially mediated ecosystem processes is warranted.

2. Sustainable Use Measures

Sustainable use is emphasized throughout the Convention. It is defined in article 2 as "the use of the components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations". In other words, Parties are to use the components of biological diversity in a way which maintains biological diversity for our use today and for our children tomorrow.

To achieve this, article 10 requires Parties to:

. integrate conservation and sustainable use into national decision-making (article 10(a));

. adopt measures for using biological resources to avoid or minimize the impacts on biological diversity (article 10(b)) (reflecting an ecosystems view point);

. protect and encourage customary use of biological resources compatible with conservation and sustainable use (article 10(c));

. support local populations to develop and implement remedial action in degraded areas (article 10(d)); and

. encourage cooperation between the government and private sectors (article 10(e)).

In addition, article 8(c) obliges Parties to regulate or manage biological resources important for the conservation of biological diversity, whether within or outside protected areas, with a view to assuring that the biological resource is conserved and sustainably used.

An important point is that the Convention reflects a new, though somewhat obvious, political awareness that the conservation of biological diversity cannot be separated from the sustainable use of its components. In other words, to conserve biological diversity as an attribute of life, the tangible manifestations of biological diversity - its component genes, species and ecosystems - must be sustainably used.

To emphasize this, the Convention refers distinctly to the "conservation of biological diversity" and the "sustainable use of its components" (or sometimes biological resources). This dichotomy also reflects the point of view of many developing countries that it is politically unacceptable to conserve biodiversity with strictly preservationist measures, a traditionally northern approach.

The following points about sustainability may be relevant:

. development and environment are viewed as inextricably linked;

. sustainability is viewed as the guiding principle for development;

. both developed and developing countries need to develop in a sustainable manner; and

. the contours of sustainability have yet to be defined but involve ecological, economic, social and political factors.

Whether the Convention's sustainable use provisions, like its *in-situ* conservation provisions, are directly relevant to micro-organisms is an issue microbial scientists and MCCs may need to address, perhaps in collaboration with biological resource managers; in other words, based on present knowledge, is the concept of sustainable use applicable to micro-organisms? Another related question is how microbial diversity is affected by unsustainable human activities involving other aspects of biodiversity (Mooney *et al*., 1995). Research is needed to determine microbial indicators of sustainability in natural and agricultural ecosystems and for environmental management (IUMS and IUBS, 1994).

It appears that the use of a micro-organism may not diminish a fixed stock of that organism, especially if the micro-organism is readily culturable. However, there may be instances where a micro-organism's use is unsustainable because of the use's impact on the micro- organism's habitat or other mutualistic or non- mutualistic organisms it is associated with it. For example, sampling in unique environments may be an unsustainable use without precautions to minimize the introduction of alien or non-indigenous micro-organisms (Castenholz, 1996; Holmes, 1996; Noble Wilford, 1996).

Furthermore, sustainability may need to be considered where bioprospectors need large quantities of a macro- organism to obtain useful quantities of a secondary metabolite produced by a mutualistic micro-organism. If the secondary metabolite is not readily synthesizable and the micro-organism is not culturable, then harvesting the macro-organism at unsustainable levels could threaten both it, the micro-organism as well as the particular ecosystem (Garson, 1996; Anderson, 1995).

H. Access to Genetic Resources

A primary objective of the Convention, and the basis for article 15, is to ensure the equitable sharing of benefits derived from the use of genetic resources with the Parties providing them. These are Parties that are (1) countries of origin (possessing genetic resources *in-situ*) or (2) Parties which have acquired them in accordance with the Convention.

The Convention defines genetic resources as genetic material (article 2). Genetic material means "any material of plant, animal, microbial or other origin containing functional units of heredity" (article 2). Functional units of heredity would include all genetic elements containing DNA and RNA. Therefore, "genetic material" would, for example, include a seed, cuttings, semen, or an individual organism. It also includes DNA extracted from a plant, animal or microbe such as a chromosome, a gene, a plasmid or any part of these. In the context of the Convention on Biological Diversity, genetic material would not include a biochemical extract if the extract did not contain functional units of heredity (Glowka *et al*., 1994), although in State practice such derivatives as secondary metabolites will likely be included in national legislation to implement article 15. The phrase "or other origin" has not been defined, but could be interpreted to include environmental samples such as soil, sediments or liquids which either include plant, animal or microbial material containing functional units of heredity or which include "naked functional units of heredity".

Perhaps the easiest way to explain how article 15 could effect the work of microbial scientists and MCCs is to use the example of Yellowstone National Park in the United States of America. In the early 1990s, popular press reports indicated that a micro-organism, *Thermus aquaticus*, isolated in 1965 from a Yellowstone geothermal pool and deposited in a national culture collection, provided the enzymatic basis for the polymerase chain reaction (PCR). The PCR technique subsequently generated tens of millions of dollars in patent licensing fees for a US biotechnology firm and then a foreign trans-national pharmaceutical company (Milstein, 1994).

Park managers looked into the legal issues that the commercial use of micro-organisms Yellowstone raised for the Park. In general natural resources within the Park were considered to be US government property: not only could they not be collected within the Park without the Park Superintendent's prior consent, but the permit issued also prevented commercial use. A loop hole in the Park's research permit seemingly allowed commercial use of micro-organisms isolated from Yellowstone's pools and used in biotechnological applications.

After consulting with microbiologists and biotechnology companies, who were initially sceptical about the Park's claim to share in the commercial benefits derived from MGRs (Milstein, 1994), the Park's research permit was revised. All specimens are now clearly retained as property of the Park Service and are transferred to collectors pursuant to a material transfer agreement (MTA) which stipulates that isolated organisms cannot be commercially developed without the Park Superintendent's prior consent (Lindstrom, 1996; Milstein, 1995). Prior consent before commercial use is the basis for negotiating a share of commercial benefits. Yellowstone is now reviewing its options with regard to what royalty percentage it should ask for when microbes coming from its pools are used commercially.

Importantly, it has been determined that future royalties received will not go to the US Treasury's general fund. Rather, they will be dedicated to Yellowstone to help support research services and education (Lindstrom, 1996). In other words, the Park's microbial diversity is helping to support the Park, in particular, education and research and, therefore, biological diversity conservation.

Ironically, even though the United States is not a Party to the Convention on Biological Diversity,^6 the Yellowstone experience represents an oversimplified version of the two major principles embodied in article 15 of the Convention. First, access to genetic resources is subject to the prior informed consent of the providing Party, unless otherwise determined by that Party (article 15(5)). Second, access to genetic resources will be subject to mutually agreed terms (article 15(4)), including benefit sharing.

The Convention's drafters linked access to genetic resources in exchange for a commitment to share benefits because of the enormous advances in biotechnology since the 1970s and its commercial promise. This was combined with the knowledge that genetic resources are the "raw material" for biotechnology, the perception that northern industrialized countries had benefited from southern countries' genetic resources with little benefit to the latter and the need to create incentives for States, in particular developing countries, to conserve biological diversity. Consequently it was agreed that, under the Convention, benefits to be shared on mutually agreed terms could be:

. research and development results (article 15(6));

. commercial or other benefits derived from the use (article 15(7));

. access to and transfer of technology using the genetic resources (article 16(3));

. participation in biotechnological research on the genetic resources (article 19(1)); or

. priority access to the results and benefits arising from biotechnological use of the genetic resources (article 19(2)).

The implications of article 15, especially with regard to private or non-governmental entities, remain to be seen because the Convention's obligations are directed toward States, their governments and governmental agencies. Implementation is in a nascent stage. Therefore, the article's implications for microbial scientists and MCCs are still unclear. However, some general observations can be made.

First, at the very least, the Convention's access and benefit sharing provisions will translate into a new global ethic concerning the use of genetic resources and the responsibilities of non-commercial and commercial genetic resource users. Given the nature of microbial diversity as well as the relative ease with which environmental samples can be collected to obtain MGRs and exchanged, the success of article 15 will very much depend on the professionalism of microbial scientists, MCCs and the biotechnology industry to ensure that their work lives up to the spirit of the Convention even if organisms originate from one of the 35 countries not yet a Party.

At the same time, microbial scientists and MCCs should strenuously argue for benefits shared to be tied back into biodiversity conservation, in general, as well as *in-situ* and *ex-situ* microbial diversity conservation in particular. Given the number of protected areas around the world, with or without extreme environments, the possibility certainly exists for a portion of bioprospecting's commercial benefits to supplement what are usually meagre protected area budgets. Many MCCs, especially in developing countries, also suffer from budget constraints and a portion of the benefits derived from the commercial use of microbes provided by an MCC could directly off-set operating costs. Microbial scientists and MCCs can help ensure that this happens.

Second, with regard to *in-situ* collection, and in some cases access to MGRs conserved *ex-situ*, it can generally be expected that to ensure benefit sharing States will either modify existing research, collecting and export controls and/or enact new "access legislation" which will, among other things, create a new regulatory procedure tailored to ensure benefit sharing fulfils national goals and objectives (Glowka *et al*, 1994; Glowka, 1995b). Prior informed consent and benefit sharing procedures will most likely be required for foreign as well as domestic collectors. Furthermore, depending on national law, access to microbial genetic resources on private property or the territories of indigenous or local communities (article 8(j)) may also require informed consent prior to access and the negotiation of benefit-sharing agreements.

Consequently, because of the potential complexities with regard to particular rights over microbial genetic resources, microbial scientists, MCCs or their professional organizations should advocate for the creation of participatory mechanisms to develop access and benefit sharing policies and legislation at the national level to enable them to contribute their unique insights on the issue. They should also be active at the global level to provide their expertise to the COP's review and development of the issue.

Third, article 15 could have important administrative and legal implications for MCCs. The primary issue is to what extent and by which means MCCs can maintain the country of origin's interests in benefit sharing after the micro- organism has been isolated, cultured and deposited, while still facilitating access to a particular culture for research and commercial use. Considering the flow of microbial genetic resources around the world and the tradition of open and virtually unrestricted access to microbial service collections, the challenge is potentially vexing. In this regard, the World Federation for Culture Collections (WFCC) should be applauded for taking steps to examine the unique implications of article 15 for MCCs to ensure that the profession and the Parties to the Convention on Biological Diversity are aware of these.

In large measure the responsibilities of a particular MCC with regard to benefit sharing and subsequent distribution of a culture will be determined by:

. the terms of an access agreement or MTA for the environmental sample taken from *in-situ* conditions and from which a micro-organism has been isolated;

. the terms of the deposit agreement;

. the terms of any subsequent MTA;

. national law;

. the legal status of the MCC (whether public or private); and

. whether a government or publicly operated MCC is located within a State or regional economic integration organisation Party to the Convention on Biological Diversity.

Fourth and finally, given the potential problems with applying article 15 to MGRs, and a general lack of awareness of the article's implications amongst microbial scientists and MCCs, the elaboration of an International Code of Conduct for Microbial Genetic Resource Collecting and Transfer could be contemplated. At its most basic, a code could establish general principles, the minimum responsibilities of States, collectors, depositors, sponsors, curators and, perhaps, end-users of MGRs, while providing guidelines for collecting and exchanging MGRs to ensure benefit sharing.

By providing a framework for governments to address the issue, access - regardless of a State's status as a Party to the Convention on Biological Diversity - could be facilitated while ensuring the spirit of the Convention is achieved. As with some existing codes for the international transfer of hazardous chemicals, MCCs could be asked to "register" or "certify" with the WFCC or an international organization overseeing the register that they will comply with the code.

An important stipulation could be that no deposits would be accepted without evidence of prior informed consent of source countries and that certified collections will follow particular standardized practices to ensure benefit sharing. A commitment by a researcher who isolates a microbe from an environmental sample to deposit in a certified culture collection in turn could facilitate *in-situ* access to environmental samples, subsequent deposit and exchange between researchers in different countries as well as benefit sharing. An incentive would be created for culture collections to register, for researchers to deposit with them and for all to comply with the code. The process to develop such a code would open the issue up to microbial scientists and MCCs and help build awareness of article 15 within the profession.

THE CONVENTION AS AN INTERNATIONAL INSTITUTION

Upon its entry into force the Convention on Biological Diversity became a new international institution composed of four entities:

. the Conference of the Parties;

. the Secretariat;

. the Subsidiary Body on Scientific, Technical and Technological Advice; and

. the Financial Mechanism.

A fifth entity, the Clearing House Mechanism for Technical and Scientific Cooperation, was recently established on a pilot basis by the Conference of the Parties (COP, 1995b). As an electronic "clearing house of clearing houses" focusing on biodiversity information exchange accessible on the World Wide Web^7, it is viewed as a primary tool for technical and scientific cooperation between the Parties. It is hoped that organizations and researchers with important biodiversity-related databases, including microbial scientists and MCCs and their professional organizations, will participate.

A. Conference of the Parties

Article 23 established the Conference of the Parties (COP) as the Convention's highest body. It is a political assembly comprising all Parties and non-Party observers. Non-states, such as environmental NGOs, scientific institutions or professional organizations such as the World Federation for Culture Collections, can attend as observers with proper accreditation.

Though the Convention's implementation is designed to be country driven, the function of the COP is to steer and supervise the implementation process and further develop the Convention. This is accomplished by:

. establishing a medium term work programme;

. obtaining scientific advice from the SBSTTA;

. setting programme priorities for the Convention's financial mechanism;

. accepting national reports by the Parties of measures taken to implement the Convention; and

. amending the Convention or initiating the negotiation of protocols (negotiation of a protocol has been initiated for the biosafety of living modified organisms, including micro-organisms).

The COP meets at regular intervals as determined by the Parties. The second meeting of the Conference of the Parties took place in November 1995 in the Jakarta. This meeting was the first to begin looking at the substantive issues associated with conservation and sustainable use of marine and coastal biodiversity (1995). A three year process was established to review this area. Agricultural biodiversity will be discussed in 1996 at the COP's third meeting in Buenos Aires. In 1997, terrestrial biodiversity will be discussed (COP, 1994).

The COP's medium term work programme will be reviewed in 1997. Through their representative organisations, such as the International Union of Microbiological Societies (IUMS), WFCC or the International Union of Biological Sciences (IUBS) microbial scientists and MCCs should collaborate and decide upon the desirability of advocating to place microbial diversity on the COP's medium term work programme.

B. Secretariat

Article 24 establishes the Secretariat. The Secretariat's functions go beyond servicing COP meetings. It plays a central role in influencing the Convention's implementation by:

. preparing the substantive papers for the COP and subsidiary bodies;

. acting as a political focal point and a neutral intermediary between governments;

. coordinating with other relevant international bodies dealing with biodiversity; and

. heightening public education and awareness of biodiversity.

At its first meeting, the Conference of the Parties decided to designate the United Nations Environment Programme as the international organization which would provide the Secretariat. The Secretariat has been located in Montreal.

Invariably, the resources of the Secretariat are limited. To be most effective, the Secretariat must occasionally draw on outside expertise. Microbial scientists and MCCs can assist the Secretariat by:

. transmitting relevant information on their activities and research; and

. providing comments and advice on substantive papers written by the Secretariat for the COP and its subsidiary bodies.

C. Subsidiary Body on Scientific, Technical and Technological Advice

Article 25 establishes the Subsidiary Body on Scientific, Technical and Technological

Advice. Its primary function is to provide the Conference of the Parties with advice related to the Convention's implementation.

The COP decides at each of its meetings which topics advice is required. The advice can fall within 5 categories (article 25(2)):

. scientific and technical assessments of the status of biological diversity;

. scientific and technical assessments of the effects of types of measures taken pursuant to the Convention;

. state of the art technologies and the ways and means of promoting their development and transfer;

. scientific programmes and international cooperation in research and development; and

. scientific, technical, technological and methodological questions.

Over the next few meetings the Subsidiary Body's *modus operandi* will be settled. Participation is open to all Parties. SBSTTA membership is multidisciplinary and is comprised of government representatives. Observers are allowed to attend its meetings. It second meeting is scheduled for 2-6 September 1996 in Montreal.

At least two major issues remain outstanding with regard to the work of SBSTTA. First, how to ensure the objectivity of the Subsidiary Body's work by practicably insulating it from undue political influence, while still maintaining a beneficial dialogue with the political process. Second, the impact of the Subsidiary Body on biodiversity-related research. While it is difficult to answer the first question at this time, clues regarding the second question's answer exist.

Pursuant to article 12(b), each Party is obligated to take into consideration the decisions of the COP on research, which will be based on the advice of the Subsidiary Body, when developing their own research strategies. Since, in many instances, developing countries do not have established research programmes, it is likely that they will draw on the Subsidiary Body's work on research more heavily than developed countries.

In addition, in April 1994, the first step towards establishing a research agenda was taken during the period prior to the COP's first meeting, when an Open- ended Intergovernmental Meeting of Scientific Experts met in Mexico City to consider organizing the preparation of an agenda for scientific and technological research (ICCBD, 1994). The COP subsequently adopted the meeting's report and the elements to assist in the preparation of an agenda it contained.

However, the COP's medium term work programme for 1995-97 does not explicitly address research as a discrete issue (COP, 1994). Instead, what may happen is that research may be discussed within the context of individual items in the medium term work programme. For example, in 1996, under "identification, monitoring and assessment" the COP will consider options for implementing article 7 (Identification and Monitoring). The COP will also appraise SBSTTA's review of methodologies to assess biological diversity (COP, 1994). Ironically, a sectoral approach may be the only way to develop the necessary policy in sufficient enough detail to prevent the Subsidiary Body's recommendations from being irrelevant.

D. Financial Mechanism

Article 20 of the Convention requires developed country Parties to provide new and additional financial resources to enable developing country Parties to meet the "agreed full incremental costs" of fulfilling the Convention's requirements. Article 21 provides that the financial resources are to be provided through a financial mechanism. The financial mechanism is to be under the guidance and authority of the COP and operated by an institutional structure decided upon by the COP.

At its first meeting the COP decided upon 13 programme priorities for funding. Among these, those perhaps most interesting to microbial scientists and MCCs include funding for:

. national strategies, plans or programmes;

. capacity building, including human resources development, for biodiversity strategies and plans;

. identifying and monitoring wild and domesticated species;

. strengthening conservation, management and sustainable use of ecosystems and habitats identified pursuant to article 7;

. projects promoting conservation and sustainable use in environmentally vulnerable areas such as arid, semi-arid and mountainous areas;

. projects promoting conservation and/or sustainable use of endemic species; and

. projects promoting technology transfer and technical and scientific cooperation.

The funding priorities have been submitted to the Global Environment Facility (GEF) which was chosen by the COP as the interim institutional structure to operate the financial mechanism. GEF is a joint funding institution jointly operated by the World Bank, the UN Development Programme and UNEP. It has been funded by donor governments with approximately two billion US dollars for alleviating 4 global environmental problems: biodiversity, climate, international waters and ozone.

The percentage of GEF funds available for biodiversity- related activities is as yet unclear. It is clear that the GEF funds will be a very small portion of the estimated seventeen billion US dollars needed annually for biodiversity conservation. As a result, Parties and researchers alike will need to identify other sources of funds including national governments, development banks and private sources such as foundations and industry.

A. CONCLUSION

The Convention on Biological Diversity presents microbial scientists and MCCs with many opportunities to contribute to global action to reverse the accelerating loss of biological diversity. We probably will not know for at least five to ten years whether the Convention will be effective.

As a first step, microbial scientists can help ensure its positive effects by first reading the Convention, becoming more active inside and outside their areas of expertise and helping the public understand why biodiversity, in particular microbial diversity, is so critical to human survival, indeed, to the survival of all life on earth.

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NOTES

2. For the purposes of this paper I will adopt Stackebrandt's use of the term 'micro-organism': those groups of organisms, whether detectable with or without the aid of an electron microscope including viruses, prokaryotes, including Eubacteria (bacteria) and Archae (archaebacteria), and eukaryotes such as protozoa, filamentous fungi, yeasts and algae (Stackebrandt, 1994).

3. While biodiversity loss is generally viewed as the unintentional loss of human activities, the international destruction of, for example, disease-related micro- organisms, such as the smallpox (variola) virus, and agricultural or other 'pests' are contrary examples. The proposal to destroy the last remaining stocks of the smallpox virus would be the first

deliberate extinction of a species (International Herald Tribune, 1996).

4. For example, there are only approximately 100 marine microbiologists in the world (Shaw Meyers and Anderson, 1992).

5. Some national legislation generally protects fungi or regulates or prohibits the use of certain implements such as rakes to avoid destroying fungal mycelium. One of the purposes of such laws is to preserve the mutualistic mycorrhizal relationship with host plants (de Klemm, 1996).

6. As of this writing, the United States of America is the only major industrialized country not a Party to the Convention on Biological Diversity.

7. http://www.istar.ca/biodiv/

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