

## Current status and future trends of Microbial Ecology in Brazil

Regine Helena S. F. Vieira<sup>1</sup>, Oscarina Viana de Sousa<sup>1</sup>, Hedda Kolm<sup>2</sup> and Leda Mendonça-Hagler<sup>3</sup>

<sup>1</sup>Universidade Federal do Ceará, <sup>2</sup>Universidade Federal do Paraná, <sup>3</sup> Universidade Federal do Rio de Janeiro

Brazil has continental dimensions, multicultural heritage and is an important emerging economy at the global level. Traditionally, the country offers a stimulating atmosphere for international collaboration, being constructed within the Mercosur block and strengthened by participation of multilateral institutions. The country is signatory of relevant legal instruments intended to protect human health and the environment, such as, the Convention for Biological Diversity and the Kyoto Protocol. Brazil contains highly diverse biomes, harboring about one fifth of the world's biodiversity. Ambitious public policies have been implemented for conservation and sustainable use of biological resources. Biotechnology, biofuels and other sectors of the bio-economy are receiving governmental investments through concerted actions fostering economic growth. In practice, environmental friendly technologies have been applied on a large scale to agriculture and industry, resulting in a greener energy matrix among countries. A plethora of programs to develop science, technology and innovation has been implemented. Brazilian research projects are mainly developed by public universities, institutions and companies, with relatively modest contribution from the private sector, although this trend is changing by the growing economy and the need to face international competition. Research activities are mostly concentrated in the south-eastern and southern states; nevertheless recent incentives are accelerating development in other regions. Considerable public investment has been applied on capacity building, by federal and state agencies to form a critical mass of scientists and engineers. Recent data show that Brazil spent about 1.5% of its Gross Domestic Product on Science & Technology, representing a fifty percent increase in one decade. This figure is lower than the top economies expenditures of typically above 2.5%, but is respectable in comparison with most developing nations. In this scenario, Microbiology has experienced strong development with considerable input from international cooperation. Various universities and research institutions grant graduate degrees in Microbiology and other graduate courses include microbiological disciplines in their curricula. Microbiology has a long term tradition in Brazil. For example, the Institute Oswaldo Cruz (FIOCRUZ) was founded more than 100 years ago and the Institute of Microbiology Prof. Paulo de Goés (IMPPG-UFRJ) over 60. The Brazilian Society for Microbiology (SBM) is celebrating 60 years of activities. Microbial Ecology and related areas followed this trend showing an expressive growth especially after 1995 when the 7<sup>th</sup> ISME was held in Santos, São Paulo. The National Environmental Microbiology meetings (ENAMA) have stimulated ecological research in different regions. Scientific societies are playing a relevant role on the development of Science and Technology, promoting communication of novel findings and motivating fruitful cooperation among scientists.

### Scientific Societies

The Brazilian Society for Microbiology (SBM) (<http://www.sbmicrobiologia.org.br>) is the major scientific society devoted to Microbiology, with divisions addressing: Basic Microbiology, Clinical Microbiology, Ecology, Soil and Environmental Microbiology, Industrial Microbiology, Virology and Education. SBM publishes the *Brazilian Journal of Microbiology* and *Microbiologia in Foco*. The SBM General Meeting (CBM), organized biannually, had expressive growth in attendance,

reaching more than 2,500 participants. Traditionally, leading microbiologists from abroad have been invited speakers of CBM. In addition to the general meeting, SBM sponsors several specialized symposia. The meeting on Environmental Microbiology (12<sup>th</sup> ENAMA) was held recently in Manaus and focused on Amazon region topics. Other Brazilian microbiological societies are: The Brazilian Society of Parasitology (SBP) (<http://www.parasitologia.org.br>), The Brazilian Society of Mycology (SBMy) (<http://www.sbmy.com.br>), The Brazilian Society of Virology (SBV) (<http://www.sbv.org.br>), and The Brazilian Society of Phycology (SBFic) (<http://www.bio.ibilce.unesp.br>). There are also major societies with interest on specific areas of Microbiology: The Brazilian Society of Soil Science (SBCS) (<http://www.sbc.org.br>), the Ecology Society of Brazil (SEB) (<http://www.seb-ecologia.org.br>), the Brazilian Society of Genetics (SBG) (<http://www.sbg.org.br>), the Brazilian Biochemistry and Molecular Biology Society (SBBq) (<http://www.sbbq.org.br>), the Brazilian Biotechnology Society (SBBiotec) (<http://www.sbbiotec.org.br>), the National Biosafety Association (ANBio) (<http://www.anbio.org.br>), the Brazilian Society of Sanitary and Environmental Engineering (ABES) (<http://www.abes-dn.org.br>), the Brazilian Association of Oceanography (AOCEANO) (<http://www.aoceano.org.br>), and the Brazilian Society for Scientific Development (SBPC) (<http://www.sbpnet.org.br>). The majority of these scientific societies publish research journals. In addition, other traditional publications are linked to institutions such as *Memorias do Instituto Oswaldo Cruz* (<http://memorias.ioc.fiocruz.br>) and *Anais da Academia Brasileira de Ciências* (<http://www.abc.org.br>). Brazil has reached the 13<sup>th</sup> position in the world for the number of indexed publications; most of them are available at the Scientific Library Online, (<http://www.scielo.br>).

### **Research framework and Microbial Ecology related topics**

The Brazilian Ministry for Science and Technology has important agencies to implement public policies: CNPq (The National Council for Science and Technology Development) is responsible for managing the National Fund for Science and Technology, Funds for Specific Sectors, International Cooperation Agreements; and also maintains several research institutes. This agency supports about 90.000 fellowships distributed in several categories, and funds research projects, events, and international programs. FINEP finances applied projects with a focus on those with interaction between academia, companies and the government. The Ministry of Education mainly supports the Federal Universities. Its major agency (CAPES) offers some 60.000 fellowships to promote the formation of human resources in Brazil and abroad. This agency constantly evaluates all the Brazilian Graduate Programs. The Ministry of Agriculture includes the public research company EMBRAPA, a world leader in tropical agriculture. The Ministry of Health includes FIOCRUZ and other health oriented institutes. Other ministries contribute to the R&D system with investments in their specific sectors. State governments also have foundations, such as FAPESP, from S. Paulo, that finance research at the state level.

Research projects on Microbial Ecology and related areas started in Brazil with the pioneer work of Joanna Dobereiner (EMBRAPA) on biological nitrogen fixation, followed by other soil microbiologists, such as Prof. João Lúcio Azevedo (ESALQ), Prof. Adam Drosdowicz (UFRJ) and Prof. Jardim Freire (Rio Grande do Sul). Studies on microbes associated with aquatic environments were focused on water quality, mainly conducted by Prof. Terezinha Martins (CETESB and USP) and groups from Rio de Janeiro, Ceará, Pernambuco, Minas Gerais and other states. Early research on Marine Microbiology concentrated mainly on the coastal ecosystems, with work conducted by Dr. Hilda Mesquita at the Oceanographic Institute, USP, and research groups from Parana, Rio Grande do Sul, Mato Grosso and Rio de Janeiro. The devoted work of these pioneers formed a

considerable number of currently active researchers that study microbes associated with natural and impacted environments. Classical microbiological methods, previously used to assess biodiversity, have been complemented over the years by modern approaches including: cultivation independent methods, genomics, metagenomics, next-generation DNA sequencing, proteomics, microarrays, advanced microscopy techniques, cytometry, and bioinformatics. International cooperation initiatives are essential for the implementation of new approaches in national R&D. The CNPq data base registers close to 250 research groups focused on Ecology and Environmental Microbiology. Current major topics of research on microbial ecology, environmental microbiology and related areas are listed below.

- Microbial diversity associated with Brazilian biomes; most studies are focused on soil and plant associated microbes.
- Genomics of microbes showing relevance to agriculture, health and biotechnology.
- Biodiversity of extreme environments, including Antarctica
- Bioprospecting for genetic resources for application (ex. Biofuels).
- Ex-situ preservation with actions to stimulate existing collections and to implement a national culture collection.
- Sanitary microbiology, assessing the validity and development of microbial indicators of water quality for drinking, recreational and fishing waters, and environmental detection of pathogens and their mobilomes.
- Microbial interactions addressing the topics of biofilms, biofertilizers (such as nitrogen fixing bacteria, mycorrhiza), biocontrol agents against phytopathogens, and promoters of soil fertility.
- Technologies to promote a cleaner environment, applied to sewage and waste water treatment, bioremediation of petroleum and other recalcitrant compounds, biocorrosion, biosensors, biomining.

## **Education**

There has been substantial public investment to implement an impressive number of Graduate Programs. To date, CAPES has certified over 3000 Graduate Courses. The first official Graduate Program established in Brazil was the Doctorate in Sciences (Microbiology), by UFRJ, in 1970. Now, there are 23 courses on Microbiology. There are also other Graduate Courses having strong interfaces with basic and applied Microbiology, such as Biotechnology, Ecology, Genetics, Public Health, Engineering, Food Science, Limnology, and Oceanography. For instance some Ecology Programs have disciplines and research on microbial diversity of natural and impacted environments. Agricultural oriented programs include teaching and research on soil microbiology. Courses on Genetics address microbial genomics, environmental metagenomics and basic microbiology. Some engineering programs focus on mitigation of anthropogenic impacts mediated by microbial processes, such as bioremediation and treatment of industrial wastes. Also, public health programs are focused on microbial infectious diseases and detection of pathogens in the environment.

The main Universities granting Graduate Degrees in Microbiology are: Universidade de São Paulo, Universidade Federal de São Paulo, Universidade Federal do Rio de Janeiro, Universidade Estadual de Campinas, Universidade Federal de Minas Gerais, Universidade Federal de Viçosa, Universidade Estadual de Londrina, Universidade Federal do Paraná, Universidade Federal do Ceará, Universidade do Estado do Rio de Janeiro. The Bachelor's Degree in Microbiology is

granted only by UFRJ, at the Instituto de Microbiologia Prof. Paulo de Goes (IMPPG). This undergraduate course focused on Microbiology and Immunology has more than 120 students enrolled. The program includes different areas in Microbiology and offers specific courses on Microbial Ecology and related disciplines. IMPPG-UFRJ has the highest concentration of PhD's in Microbiology working in a single Brazilian institution. Among its faculty there is an expressive group devoted to education and research on Microbial Ecology, Biotechnology and Environmental Microbiology. Other universities offer Biology bachelor degrees with major in Microbiology. In addition, Microbiology courses are required for students seeking bachelor degrees in Biology, Chemistry, and various professional schools (Nutrition, Food Science, Engineering, Medicine, Dentistry, Pharmacy, etc.).

### **Opportunities for International Cooperation**

Most Brazilian funding agencies carry international cooperation programs (CNPq, CAPES, State Foundations, etc). Universities and research institutions welcome cooperative projects, courses, visiting professorship programs and international training of faculty members. Recently, a new program called "Science without Frontiers" was launched by the government to increase substantially the number of fellowships, allowing Brazilians to study in other countries. CNPq also supports foreigners from developing nations to study in Brazil. Official protocols on science, technology and innovation (R,D&I) are in progress with several countries and economic blocks, offering plenty of opportunities for international cooperation.

### **Concluding remarks**

Microbial Ecology and related areas are progressing well in Brazil. Students and young researchers demonstrate enthusiasm toward the topics being developed by leading researchers. Also, there is a tradition to seek training abroad at the main centers performing cutting-edge research. Financial incentives for international training are available. In this context, scientific societies, especially SBM, ISME and ASM, are instrumental in promoting exchange and further development of scientific cooperation among microbiologists worldwide. Brazil implemented regulatory agencies and legal frameworks (Intellectual Property Rights, Biosafety Law, norms applied to biological resources, regulation of research with humans and so on) to facilitate international agreements. Brazil more than doubled its expenditures on RD&I, being considered an emergent global player. Agriculture and Biosciences are priority areas of research in the country. The described current scenario is quite favorable to Brazil. In this context, Microbiology and environmental related sciences can play a pivotal role in the quest to achieve sustainable development.

Corresponding author: L. Mendonca-Hagler; e-mail: ledacristinam@hotmail.com