

DNA Barcoding: Society and technology dynamics in the Indian context

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Abstract: Access to biodiversity for barcoding, and ethical questions in the context of barcoding technology, have to be framed in terms of consequences for the livelihoods and culture of the stewards of biodiversity and the environment. Stewards of biodiversity must be involved in the development of barcoding technology and its use as active participants. This paper examines these issues in the Indian context, where a national biodiversity policy has been enacted.

Introduction

DNA barcoding as a scientific idea, initiated by Prof. Paul Hebert in 2003, has been attracting international attention for its significance in advancing the taxonomy of life forms. The objective of DNA barcoding is to transform conventional taxonomy by digitizing the identity of a given species. DNA barcoding employs sequence diversity in short segments of standardized regions of the genome as a digital system for species recognition (iBOL Project: Overview of Research 2008). Linnaean taxonomy, which began 250 years ago, is based on phenotypic separation of species by morphological dichotomies. Stoeckle *et al* (2004) point out that Linnaean classification is an abbreviated label for morphology of a species; the short sequence is as an abbreviated label for the genome of the species.

DNA barcoding promises several useful applications apart from species recognition. Ensuring food quality and controlling agricultural pests, disease vectors and invasive species are some of the areas in which barcoding technology may be deployed. The digital codification system that barcoding seeks to create could lead to innovations in electronics, bio-informatics and devices such as hand-held barcoders.

Although a few million species have been discovered and identified, many millions more, including micro-organisms, remain to be discovered and documented. Whether a species is endemic to a geographical region or is widely distributed, barcoding of life is truly international in scope. However, geographical regions are divided into modern nation-states, and each nation-state decides whether or not to sign international treaties based on national interest. The 1992 Convention on Biological Diversity (CBD) has been signed by 168 countries (www.cbd.int/convention/parties/list). The Government of India, for example, signed the CBD on February 18, 1994, but the United States of America is not yet a signatory to the CBD. The objectives of the international Consortium for the Barcode of Life and those of the CBD are related. Members of the iBOL consortium are 'committed' to the regulatory

framework established under the Convention on Biological Diversity (iBOL project: Research Overview, 2008, p.14).

II

Society and technology dynamics

Throughout history human beings have interacted with nature through the medium of technology. This interaction has transformed nature while simultaneously transforming society and social relations. Since the latter half of the 20th century, science and technology on the one hand and economy, polity and culture on the other have been intimately interconnected so that it is now difficult to maintain the classical distinction between science as the *act of knowing* and technology as the *act of doing*. Science has undergone a cultural revolution, from academic science and its associated values like disinterestedness, to post-academic science and its associated values like profit and efficacy (Ziman 1996).

Technoscience, a concept first coined by the Belgian philosopher Gilbert Hottois, captures the character of science in the 21st century (Latour 1987, Haraway 1998). Modern biology has become a technoscience. For example, mapping the genome of a crop plant or an animal species is not merely aimed at description of the whole complement of the genes but also at understanding the functions of the genes for possible technological interventions. Similarly, DNA barcoding enhances our descriptive understanding of the diversity of species and may pave the way for new interventions. The pursuit of knowledge about, and manipulation of, life forms or parts thereof raises ethical questions. Such questions in the context of DNA barcoding should be framed in terms of consequences—intended and unintended—of barcoding for individuals, groups and communities.

The consequences of barcoding have to be visualized at the time of accessing biodiversity for barcoding. For example: what are the consequences—intended and unintended—of barcoding a species that has commercial value and on which a particular community depends for its livelihood? The community and its representatives must be involved in the exercise. Similarly the consequences of barcoding a plant species that has medicinal value have to be anticipated. If the consequences pose risk to the community, risk analysis must be undertaken by an independent third party in collaboration with the community. If the potential loss to the livelihood of the community arising out of barcoding turns out to be greater than the benefits, then the species should not be barcoded until alternative livelihoods are made available to the community. Also, any benefits resulting from barcoding have to be shared with the community for conserving the species.

Democratization of decision-making regarding technological choices, regulating technology and equitable access to technology—has assumed significance in the context of economic and social development. It is against this backdrop that the study on barcoding technology and its interface with social, ethical, economic and political domains will be explored.

III

Objectives

The present exploratory study attempts to:

- Understand technical issues relating to barcoding in the Indian context, as well as relevant ethical, social, economic and political issues, such as dealing with prior informed consent, risks, access and benefit sharing.
- Provide a perspective from the viewpoint of actual or future users, beneficiaries, and participants of the technology, including scientists, policymakers, and in particular, the owners or stewards of the natural resources being barcoded.

I drew upon the Indian legislation on biodiversity to examine the policy environment which has implications for DNA barcoding in India. Using a technique called theoretical sampling, I have so far interviewed 10 scientists based in Hyderabad, belonging to the disciplines of molecular biology, taxonomy and plant breeding. They were selected on the basis of their involvement in barcoding and/or their work in a related field. One of them is involved in a project on barcoding bird species in India. I also interviewed representatives of two civil society organizations (CSOs). I relied on the material collected from the interviews with scientists and the CSOs since, to the best of my knowledge, there are no users of barcoding technology among members of the general public. On the basis of the findings of this small-scale study we cannot draw generalizations, but the study raises issues that have to be explored further. This paper, therefore, should be seen as a report on work in progress.

IV

Findings and discussion

The “mega hotspots” of biodiversity are located in the developing countries of the South, including India. As in many developing countries, communities in India have acquired knowledge regarding various species of crop plants, medicinal plants, and animals over time. This knowledge is based on trial-and-error to determine the usefulness or otherwise of each species. The communities have evolved their own local taxonomies that are shared among the community members.

Potential of DNA barcoding technology

My exploratory field work indicates that scientists recognize the need to describe and document the wide-ranging biodiversity that remains to be explored in India. They stated that DNA barcoding is a valuable technology for this purpose. In India, as in many other countries, there is a perception that taxonomy is a less attractive specialty (Prathapan *et al* 2006). Perhaps one of the reasons is that scientists seem to attach more ‘glamour’ to a research career in molecular biology (Haribabu 2000). Research relating to DNA barcoding may change the situation and fill the shortfall in the number

of taxonomists. This calls for focused training programs that attract young scientists.

The scientists in the study indicated that over time, especially during the last 25 years, concerted efforts on the part of the government and the scientific institutions engaged in teaching and research in molecular biology have resulted in creating a competent community of molecular biologists in a few institutions in India¹. According to one of the scientists interviewed, biologists in these institutions are highly productive and are in a position to train scientists from other developing countries in the science and art of barcoding as these institutions are equipped with state-of-the-art infrastructure. Because the concept of DNA barcoding is very recent, scientists in many universities and research laboratories have not started focusing on this new technology. To the best of my knowledge there are only three projects underway at present. However, the scientists expressed the view that DNA barcoding will create new interest in taxonomy among scientists. Further, scientists suggested that conventional taxonomy will not disappear, rather that DNA barcoding will be a complementary tool in the hands of scientists engaged in taxonomy.

One of the scientists who participated in the Barcoding of Life conference held in Taiwan in 2007 mentioned that barcoding will be extremely useful to identify a large number of small species. Another scientist, who is heading an *ex situ* organization supported by public funds, suggested that barcoding will be useful in assigning specimens to species. Barcoding also helps to avoid duplication of entries of varieties and landraces of crop species in *ex situ* conservation, and gene bank accessions can be verified with the help of a barcode. Further, scientists suggested that barcode technology will facilitate conservation of biodiversity as well as monitoring and detection of foreign plant and animal material in food and pharmaceutical products. DNA barcoding will help in separating the original species from look-alike species. For example, *Pterocarpus santalinus*, popularly called red sanders or red sandalwood, is highly valued for its timber. It is a rare species that grows only in the hill ranges of Southern Andhra Pradesh. If it is barcoded, the information can be used to separate the rare red sandalwood from look-alikes.

Institutional arrangements for accessing biodiversity

The Government of India is a signatory to the CBD and the Parliament of India has ratified the Trade Related Aspects of Intellectual Property Rights. Parliament passed the Protection of Plant Varieties and Farmers Rights Act in 2001, legislation designed to protect plant varieties. The following year Parliament passed the National Biological Diversity Act to give effect to the CBD in the Indian context. The Act was the outcome of a process of consultations involving scientists, policymakers and CSOs, and treats all biological resources in the country as national resources. The two Acts, which extend to the whole of India, are intended to protect India's bio-resources. The Protection of Plant Varieties and Farmers' Rights Authority and the National Biodiversity Authority (NBA) have been empowered to take all

necessary steps to achieve the objective of the two Acts of Parliament. The objectives of the NBA include: conservation of biological diversity, sustainable utilization of its components, and equitable sharing of the benefits arising from utilization of genetic resources.

While the NBA functions at the national level, State Biodiversity Boards (SBBs) operate at the state level and Biodiversity Management Committees (BMCs) at the level of local bodies (*Panchayat* at the level of the village, municipalities at the level of small towns) to promote conservation and documentation of biodiversity as well as sustainable use of its components.

Some of the salient features of the National Biological Diversity Act are:

- Regarding the regulation of access to biological diversity, a person who is not a citizen of India (or is a non-resident Indian) shall not obtain a biological resource occurring in India, or the knowledge associated with it, without securing the prior approval of the NBA. The same applies to any corporate body, association, or organization not incorporated or registered in India (or incorporated or registered in India but having no Indian participation). Further, no person shall transfer the results (except publication of research papers or dissemination of knowledge in any seminar or workshop) of any research relating to any biological resources occurring in India (or obtained from India) for monetary consideration or otherwise to any person who is not a citizen of India or any corporate body, as mentioned above, without obtaining prior approval of the NBA.
- According to the Act, no person shall apply for any intellectual property right (IPR) in or outside India for any invention based on any research or information on a biological resource obtained from India without obtaining the prior approval of the NBA.
- The NBA may, while granting approval for filing the application for an IPR, impose a benefit-sharing fee, a royalty, or both. The NBA may also impose conditions including sharing of financial benefits arising from the commercial utilization of such rights. This provision does not apply to those cases in which the application for the right comes under the purview of any law relating to the Protection of Plant Varieties and Farmers' Rights Act. Regarding the proceeds of the benefit sharing, the amount of money determined by the NBA would have to be deposited in the National Biodiversity Fund.
- No person who is a citizen of India or corporate body, association or organization registered in India, shall obtain any biological resource for commercial utilization or bio-survey, bio-utilization for commercial utilization without first notifying the SBB. However, this provision does not apply to the people and communities of the area, including growers and cultivators of biodiversity and practitioners of traditional medicine.

Reactions to the National Biological Diversity Act

Although the Act has been welcomed as a step in the right direction, scientists seem to differ in terms of what it will do to promote the basic

science of taxonomy. Prathapan *et al* (2006) argue that the Act, by declaring the bio-resources as national resources, will curtail the freedom of scientists and discourage research in taxonomy, as species identification requires international collaborative research for comparing the specimens before assigning them to the species. They argue: "...with the introduction of the Biological Diversity Act, we have completely lost the moral authority to use these (exotic germplasm obtained earlier from other countries) without the formal permission and benefit-sharing with the respective countries of origin."

Another view within the scientific community is that DNA barcoding has to be carried out in accordance with the provisions of the Act as it provides a framework of rules regarding access to biodiversity, use of its components, and benefit sharing. Scientists mentioned that a democratic decision has to be taken regarding which species in the country have to be barcoded, given the fact that there are endemic, endangered and commercially significant species. Since the legislation treats all bio-resources as national resources, accessing the species for barcoding has to be based on formal approvals at different levels. The scientists are of the view that the barcoded information has to be kept in the public domain except in the case of some endemic species which have commercial applications. In this connection, they strongly argue that in any international collaboration Indian scientists should not part with samples of species to be barcoded to collaborating scientists in foreign countries. The samples should be kept in a national repository, or bio-bank, and the sequence information may be shared with scientists in other countries.

The National Biological Diversity Act and CSOs

The CSOs seem to hold that the Act should not give exemption to the Indian scientists of corporate bodies to access biodiversity just by giving prior information to the SBBs, as mentioned above. They should seek prior permission to access biodiversity as in the case of individuals who are not citizens of India and corporate bodies not registered in India or registered in India without Indian participation (www.kalpavriksh.org). The CSOs want the same rules applied to Indian citizens and corporate bodies, believing that their motivation in accessing biodiversity may be no different from that of outsiders. One CSO, Gene Campaign, believes the Act falls short of fulfilling the national needs, suggesting that the Act hampers research and is not clear on the question of IPRs (<http://www.genecampaign.org/>).

It appears that there are differences within the scientific community regarding how the provisions of the Act will influence scientific research. However, this needs to be explored further. The CSOs seem to hold the view that access to biodiversity especially for corporate bodies—both Indian and foreign ones—should be based on the same rules.

Prior informed consent

In India, communities have been involved as custodians or stewards in conserving germplasm of crop plants, horticulture, medicinal plants and

some species of animals *in situ* over the years. For example, some species are protected by the communities in the form of sacred groves, which may contain endangered species. Communities do not use plant species or parts of the species in the sacred groves. Some species of plants have religious significance among Hindus. For example, *Aegle marmelos*, popularly called Bilva tree, is conserved by planting it in the premises of Hindu temples. Another example: *Ocimum tenuiflorum*, popularly called Tulsi, has some medicinal properties. It is protected by planting it in the backyards of households to have ready access to the plant for medicinal purposes. In fact, Hindus accord a sacred status to the plant and worship it so that it is not neglected.

Another example: Jeypore tract—comprising northern parts of Andhra Pradesh, and contiguous parts of Orissa and Chattisgarh—is populated by tribal communities and is considered to be the place of primary origin of rice in India. The tribal communities have been conserving the landraces and varieties *in situ*. In India some species of goats and sheep reared and bred by some communities, have been shown to have genes that confer resistance against some diseases. In other words the communities that conserved the species assumed the role of custodians or stewards.

These and other examples suggest that any attempt to barcode such species must require the prior informed consent of the custodians or stewards. Such consent must be taken at different levels: at the level of communities and religious organizations, local self-governments like the village *Panchayat*, in addition to the SBBs and the NBA as specified in Section 3 of the National Biological Diversity Act. The stewards and or their representatives must be involved in the consent-seeking process for barcoding and in negotiations regarding the sharing of any benefits arising out of the use of components of biodiversity if the components are found to have potential commercial applications. Communities become vulnerable if they provide information for the purpose of barcoding about a species on which they depend for their livelihood. The information may be used by others, and the community could ultimately be deprived of its livelihood.

As a part of the process of democratization of barcoding technology, efforts should be made to involve members of the communities in barcoding the species which they have been conserving. Such involvement could expedite the barcoding of millions of species. However, the consequences of barcoding—especially of species which provide livelihood for communities—need to be addressed in consultation with community representatives before barcoding takes place. They must be informed about the benefits of barcoding of the genes that have commercial value, and their rights as stewards of the species. The barcodes of the species must be shared with the communities, and the members of the community should be trained in using the barcoded information.

Conclusion

DNA barcoding is a relatively new technology, and to date only a few scientists have initiated work on barcoding of some species. Similarly, civil society and its organizations have little awareness of this new technology, and at present no exclusive legal or administrative framework exists for regulating barcoding technology. In this context, provisions of the National Biological Diversity Act may be used to access biodiversity for barcoding and to ensure benefit sharing. However, as scientific organizations in the country start participating in barcoding activity in a big way the barcoding technology may throw up new ethical, social, economic and political issues.

Long-term research covering different regions of the country is needed to document the issues relating to the dynamic interface between DNA barcoding technology on the one hand and ethical, social, economic and political domains on the other. The outcome of such research may either suggest suitable amendments to the national biodiversity legislation, or lead to new legislation to facilitate and regulate DNA barcoding in India. Attempts to make any necessary changes to the legislation, or to evolve new legislation, should be initiated by the stakeholders: communities that have been the custodians of biodiversity and their organizations, local governments, the scientific community engaged in barcoding work, and society at large.

Notes:

1. The Government of India established the Department of Biotechnology in 1986 and invested a significant amount of resources over the years to support research and the state-of-the-art training in molecular biology and biotechnology in the conventional universities, agricultural universities and mission-oriented research laboratories (see the website: <http://www.dbtindia.nic.in/>). The Rockefeller Foundation, as part of its International Program on Rice Biotechnology, supported research and capacity building in molecular biology and biotechnology during 1989-2000 (see the website: www.rockfound.org).

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