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Microbial diversity

Microorganisms are ubiquitous, live in most inhospitable sites across the various ecosystems and are considered by some as 'masters of the biosphere'. Their total number on earth is estimated to be, 4–6 × 10^{30}. This gives reasons enough to microbial biologists to be in sixth heaven since no more than 1–5% of this diversity has either been cultured or its functionality assessed. On a global front, Alan T. Bull has summarized these developments in an edited volume entitled *Microbial Diversity and Bioprospecting* 2004.

India with its vast ecosystem scenario is ideally placed for study of not only plant and animals but also of microbial genetic resources. This special section attempts to bring together global developments with Indian perspectives in mind. Considering the limitations of space in such a fast developing area of activity, coverage is restricted largely to bacterial and fungal diversity components. Also described is a working action plan that has been built through a participatory process across the academia, students, NGOs, industry and subject experts.

Cyanobacterial biodiversity and potential applications in biotechnology

Cyanobacteria represent the oldest living photosynthetic system whose fossilized remains have been observed in Precambrian, 2 to 3.5 billion years ago. Their long evolutionary history has meant adaptation to various stressed habitats, physiological functions and wide geographical representation. Thajuddin and Subramanian describe (**page 47**) that as primary producers of freshwater and marine ecosystems they play an important part in carbon cycling, and as nitrogen fixers through heterocystous forms, they contribute substantially towards the rice ecosystem. On rocky substratum they occur as epilithic and endolithic communities of ecological consequences and adaptability. Cyanobacteria are currently being used in various sectors including human health.

Fungal diversity, conservation and prospecting: Indian perspectives

Fungal diversity estimates, like other microbial groups, are in a state of flux with the discovery of putative endophytic forms in woody trees. This places the earlier fungal estimates of 1.5 million on a rethinking path. What is however to the credit of Indian mycologists is the description of approx. 27,000 species from India when the total described forms stand at around 74,000. It goes to the credit of C. V. Subramanian and his group at the University of Madras that among approx. 205 new fungal genera described from India, about 32% were described by his group.

Fungi are key component as decomposers of plant and animal matter on the globe that return the much needed nutrients to the soil. As mutualists of plants, arbuscular mycorrhizal (AM) fungi are a key partner in nutrient acquisition in stressed habitats. Add to these the much prized truffles as food delicacy which are to be hunted by trained pigs and dogs! However, all is not well since they can be devastating pathogens; the case of *Phytophthora infestans* on potato and the Irish famine of the nineteenth century is much too well known to be forgotten. The story of penicillin and *Penicillium chrysogenum* is a living example of their deed for human welfare or current applications as hosts for heterologous expression of recombinant proteins. Authors of this paper led by Manoharachary (**page 58**) try to put together, in the limited space available, overall dimensions of fungal diversity, examples from some unique ecosystems and also suggest a road map for conservation and future prospecting.

'Unculturable' bacterial diversity: An untapped resource

The era of modern molecular biology has opened up new frontiers of investigations in the study of ecosystems dynamics and community structure. Metagenomics, i.e. total genome of an ecosystem, permits investigations of the so-called 'hidden' or 'unculturable' world and exploitation of this gene pool in biotechnological exploitations. Sharma and others describe (**page 72**) how PCR amplification of DNA and/or RNA direct from environmental samples of interest coupled to preparation of libraries in fosmids and bacterial artificial chromosome (BAC) provide opportunities to deal with large fragments of DNA for study of functional diversity within the unculturable pool, that has resulted in characterization of various enzymes such as amylase, chitinase, lipase, xylanase, etc. Application of this approach is highlighted citing the recent work of human genome fame, Craig Venter, who has utilized whole genome shortgun sequencing of microbial populations collected *en masse* from Sargasso Sea near Bermuda.

Extremophilic microbes: Diversity and perspectives

Microorganisms are the real survivors when it comes to stress management. As a consequence they have occupied habitats that no other living being would want to, but what is amusing is that in doing so they are providing human beings the bounty of bioactives and enzymes that can work under harshest of the conditions, be it pH, temperature, salt concentration, osmotic pressure or organic solvents. While culture-dependent methods provided the first archaean member, *Sulfolobus*, from the thermal springs at the world famous Yellowstone National Park, it also provided the scientific community, the Master Crafter of Molecular Biology, *Thermus aquaticus* which has revolutionized study of diversity, phylogenies and ecogenomics. Satyanarayana and others describe (**page 78**) that while several groups in India have attempted study of extremophilic microorganisms, major research focused on thermophilic eucaryotes especially fungi. A major group where one of the authors has been involved actively, is the domain of cold-loving forms, the pscychrophiles wherein Antarctic samples from the Indian expeditions have led to recovery of new organisms.

Microbial diversity in desert ecosystems

Desert ecosystems are indeed unique since this otherwise lifeless arena is full of microhabitats that are a hallmark of microbial diversity and functionality. Major habitats include, patina or desert varnish, cryptobiotic crusts, saline playas and rhizosheath, each exhibiting unique spectra of microorganisms among which cyanobacteria, being autotrophic in nature, play an important role.

The cryptobiotic crusts are largely dominated by cyanobacteria in harsher sites and by lichens in intermediate sites. Diazotrophs are, however, common component of cryptobiotic crusts in deserts. Rock outcrops that account for app. 13,200 km^2 areas in Rajasthan are also colonized by lithic communities comprising cyanobacterial–lichen crust or desert varnish. According to the authors, Bhatnagar and Bhatnagar (**page 91**), the diversity estimates for rock surfaces are higher from soils in Indian desert.

Microbial diversity: Applications of microorganisms for the biodegradation of xenobiotics

Natural microbial diversity has provided invaluable service to mankind as scavengers of undesired molecules in the environment through their catabolic machinery and adaptability. During the early part of the last century use of chemicals as crop protectants and those derived from industrial activity was largely confined to molecules that did not differ drastically from those reaching the natural ecosystems from plants and animal remains and their degradation products. However, with the advent of industrial technologies to improve the lot of humanity on the earth, new synthetics came into market. Once these molecules reached the soil system or a water body, it brought about perturbations in the existing indigenous microbial community. What has not been possible through 'nature engineering', has been achieved through human intervention, i.e. genetic modification of microorganisms (GMOs). Microbe-based technologies for remediation of pesticides in the soil environment, clean up of oil spills in marine ecosystem and degradation of other recalcitrant is not only a reality but is looked up with favour in 'green technologies' of today and future. Jain and others provide (**page 101**) examples from global and Indian work to show that this area of research can do well with the new gene pool for which diversity search is necessary.

Genetic diversity of pathogenic microorganisms

While a majority of microorganisms are useful to the society, a small number with high genetic diversity is a cause of great concern on account of disease causation and interference with human health. Among pathogenic forms, considerable global effort is underway to understand the genetic variability. According to authors, Virdi and Sachdeva (**page 113**), advent of molecular tools especially multilocus enzyme electrophoresis (MLEE or MEE) has greatly helped understand genotypic variability and clonality concept as applied to pathogenic bacteria. According to them, 'horizontally acquired Pathogenicity Islands (PAIs) are one of the major contributors to the pathogenic life style of certain bacteria'. PAIs can result in transformation of a benign strain into a potential pathogenic form, thus making the task of a pathologist not only difficult, but appropriate and timely interventions impossible.

Rumen microbial ecosystem

Rumen, the so-called fourth stomach of cow, buffaloes, and the likes, harbours a plethora of microorganisms represented by bacteria, ciliate protozoa, anaerobic fungi, archaea and bacteriophages. What is indeed of great interest is the balance of equilibrium by way of species richness represented by such a large consortia of aerobic to anaerobic forms that does not get disturbed even when the animal diet undergoes a change. Kamra describes (**page 124**) that this balancing act is a consequence of the prevailing anaerobiosis, high buffering capacity of the system, resulting in osmotic pressure and the ensuing competition among the microbial members for survival. Rumen is a storehouse of anaerobic fungi found nowhere else that play a very dominant role in degradation of lignocellulosic component of the feed.

Diversity of plant growth supporting microorganisms

Association of microorganisms and plant system is considered not only intimate but also one where positive and negative influences occur within a group with ease. However, from the view point of beneficial influence on plant health and fitness, functionality of the effective microbial populations is essential. Since Indian soils are deficient in nitrogen and phosphorus, considerable research effort has been directed towards assessment of potentially exploitable forms. Whereas symbiotic rhizobial diversity has been a focus of attention for legumes, associative forms such as *Azospirillum* have been investigated for cereals. However, free-living, heterotrophic growth promoting rhizobacteria have received considerable emphasis lately. Tilak and others discuss (**page 136**) specialized endophytic bacterial communities of especially agricultural crops that are a focus of attention by virtue of their adaptive behaviour, functionality and phylogenies.

Microbial diversity: Strategy and action plan

Johri and others describe (**page 151**) a working plan on Microbial Diversity for the country that is based on an exhaustive survey undertaken in the country, concept notes and deliberations in a workshop wherein various groups, right from school students to academicians had participated. Representative examples of a few ecosystems that require immediate attention for floristic survey are provided. While interests of various stakeholders have been taken into consideration, the contents of this article are obviously open to discussion since study of microorganisms and their exploitation can find various hues.

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