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# Guest Editorial

## A Decadal Status of Microbiological Research in India

Microbes play an important role in our life; they are responsible for the upkeep of the environment *via* agriculture, health and medicine and a considerable proportion causes infectious diseases in humans, plants and animals. Microorganisms also have biotechnological applications in industry and immunology. The discipline of microbiology has received a tremendous boost in recent years due to the advances in DNA sequencing techniques and discovery of newer computational tools to explore the microbial diversity and newer functions of microorganisms that were hitherto not known. Discoveries on microbiome have now reinforced the idea that microbes have profound effect on our environment, human health, and also in climate change. While there has been a tremendous progress in research in these areas worldwide over the last decade, in India research in these areas is also gaining momentum. This special issue encompasses ten articles providing overviews of the work that is being carried out in India in the different areas of Microbiology.

With the advancements in next generation sequencing technologies, it is now feasible to obtain good quality of genome and metagenome sequences for the microorganisms at comparatively low costs.The broad objective to predict the ecological significance and functional roles played by the microorganisms has been predictable with the genome sequences available for the microbes. Although, there are comparatively less genomic and metagenomic studies from India the science of "omics" has been rapidly growing as an emerging field of research as evident from the articles on genomics and metagenomics. Also, traditional methods like polyphasic approach has contributed enormously in the identification and characterization of novel taxa of prokaryotes from India since 2006. Review of taxonomic descriptions suggested that a total of 332 new species from diverse niches like soil (agricultural/ contaminated/desert), water (fresh/marine/hot springs), sediments and insects have been found. In addition, bacterial diversity from extreme habitats like Arctic, Antarctica, Himalayan glaciers and stratosphere has also been explored by some researchers from India. Studies from these environments not only identified different species of psychrophiles inhabiting these areas but also throws light on their exclusive survival mechanisms for adaptation to cold temperatures. Some of these strategies include capability to synthesize cold tolerant enzymes, anti-freeze proteins, modulating membrane fluidity and transcription of many cold-inducible genes in response to the cold temperature. Again, genome sequencing has played an important role in generating genomic information and understanding the adaptation of these psychrophiles to extreme cold conditions.

In the last decade, microbiology has advanced the agricultural practices and agronomic management by assessing the diversity and functions of beneficial soil microbes and their efficient use as inoculants in sustainable agriculture. These beneficial microbes are used as an alternative to chemical fertilizers and pesticides to improve soil health, crop yield and biodiversity. In addition to bacteria, agricultural microbiology uncovered diversity of fungi and nitrogen fixing cyanobacteria from soil systems. Major focus was to improve biological nitrogen fixation and biocontrol by these genetically diverse microorganisms. Therefore, agriculturally important microbes play a significant role in biocontrol, biofertilizer, stress tolerance by plants and bioremediation. However, it is unfortunate that in India while we use many bacteria as inoculants to boost agricultural production, but have not yet started the use of genomics to decide whether or not the traditional strains that are in use should continue. This can now be easily concluded if there are any virulence or

pathogenic islands in these bacteria.

Applications of microorganisms further extends to industrial microbiology where selected strains possess ability to produce important biomolecules and products. Initially, commercial market was dominated largely by fermentation products, but with advances in molecular studies many advanced therapeutic biomolecules, antibiotics (rifamycin), enzymes (amylases, cellulases, proteases, phytases, pectinases), organic acids (lactic acid, citric acid, gluconic acid), exopolysaccharides and amino acids have recently been branded by various industries in India. Likewise, bacteria capable of degrading oils and paraffin were used as a technology to prevent deposition of paraffin in oil wells and eliminating oils from contaminated sites. In an attempt to use microbial processes in decreasing contaminants and waste treatment, various species of bacteria were identified that primarily remediate these contaminated sites accompanied by production of biofuel (methane). Additionally, bacteria belonging to genus *Bacillus* produce biohydrogen and biopolymers like polyhydroxyalkanotes (PHA) that are used as natural bioplastics as an alternative to non-biodegradable plastics. These bioplastics have biotechnological applications and the details have been reviewed in the environmental biotechnology section. Microbe-assisted biodegradation and bioremediation of aromatic compounds namely chlorophenol, p-nitrophenol (PNP), aminophenol, chloronitrophenols and their derivatives have been extensively studied. Similarly, aerobic and anaerobic pathways of degradation of organochlorines (aldrin, dialdrin, endrin, heptachlor, chlordane, endosulphan, lindane, polychlorinated biphenyls), organophosphates (methyl parathion), hydrocarbons and crude oil in bacteria have been deciphered. Subsequently, the information is used for engineering the important strains so as to construct efficient consortia of strains for removal of these pollutants and chemicals from the environment.

Indian microbiologists have done an impressive amount of work in different areas of microbiology and mycology. The article on medical microbiology that focusses on the epidemiology of important pathogens belonging to bacteria, viruses and protozoans namely rotaviruses, human immunodeficiency virus (HIV), *Mycobacterium tuberculosis*, *M. leprae*, *Salmonella typhi*, *Helicobacter pylori, Yersinia enterocolitica, Leishmania, Plasmodium falciparum, Vibrio cholerae* and *Wuchereriabancrofti*. Medical microbiologists are actively involved in research and development related to the diagnosis and vaccine development of the infectious diseases caused by these pathogens in India. This has led to the development of kits for detection of HIV, tuberculosis, virulent typhoid and leprosy, dengue, cholera etc. A number of potential candidate vaccines have also been developed in the last decade against virulent *S. typhi*, *M. leprae*, *B. anthracis* and *V. cholerae.* In addition to these bacterial and viral pathogens, fungal infections are also very common in India due to tropical environment and a substantial amount of research has been done in this area. The article on medical mycology focusses largely on the epidemiology, treatment and clinicals aspects of the fungal diseases like invasive candidiasis, mucormycosis, antifungal resistance in Intensive Care Units, keratitis, allergic bronchopulmonary aspergillosis (ABPA) and sporotrichosis. In addition to this, the article also emphasizes ongoingresearch in various institutes on specific species of fungi like *Candida auris*, *Candida tropicalis*, *Apophysomyces variabilis*, *Malassezia* and dermophytes. Further, the last article on human gut microbiome research in India provides an overview of the work that is being carried out in this emerging field. Human microbiome plays a vital role in healthy and diseased state of the body. Microbial profiling to identify the diversity and richness of different microbial species in diverse health conditions has enabled scientists to understand the role of microbiota in maintaining overall health. The inferences from the preliminary microbiome studies highlight that the Indian population harbours a very distinct microbiota attributable to their diet and lifestyle as compared to other parts of the world.

It is hoped that this collection of articles will be useful to the readers interested in knowing about the current state of microbiology research in India.

There has been some delay in putting this report together due to some challenges and we take entire responsibility for that. We also proffer our apologies in advance for any inadvertent omission of the work carried out by our colleagues at large.

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