

BOOK REVIEWS

Annual Review of Microbiology, 2022.

Susan Gottesman, Andrew L. Goodman and Caroline S. Harwood (eds). Annual Reviews, 1875 S. Grant Street, Suite 700, San Mateo, California 94402, USA. Vol. 76. xii + 782 pages. Price: US\$ 118.

Among all life on this planet, microorganisms, without question, are the first to have arisen during evolution and are by far its most numerous representatives^{1,2}; despite their tiny size, as reflected in their name, they constitute approximately twenty percent of the global biomass³. Arguably too, they are the most diverse in terms of species abundance⁴. Microbes are present and grow in a vast range of niches and habitats. Some of them provide economic benefits to humankind (for example, through symbiotic nitrogen fixation in legumes or by fermentation processes), while some others are responsible for severe diseases in humans, animals and plants. The 2022 volume of the Annual Review of Microbiology is a compendium of around 35 reviews on various topics within this broad discipline. The reviews have been curated by three editors: Susan Gottesman, Andrew Goodman and Caroline Harwood.

While undertaking the difficult task of reviewing a collection of otherwise disconnected review articles, I have attempted to render it easier for the reader by grouping several of them into common themes or ideas. One way of grouping would be with respect to the classification of microorganisms. Two of the three kingdoms of life, bacteria and archaea, are comprised entirely of microbes, and the third kingdom, eukarya (which includes animals and plants), also has some microbial representatives such as yeasts, fungi, microalgae and protozoa. All viruses are also classified as microorganisms. Each of these categories is indeed covered in the various articles of this volume, but I have chosen not to use this categorization for my description below with but one exception. The exception pertains to the group of Protozoa, which include Plasmodium and Toxoplasma, within a sub-group called apicomplexans, that are responsible for serious human diseases (malaria and toxoplasmosis respectively). This volume has four reviews on these parasites that cover Plasmodium development in the mosquito vector, mechanisms for its release from infected liver or blood cells in humans, how apicomplexans invade host cells, and some functions of Toxoplasma that have evolved to mediate alteration of

the epigenetic programme of the host cell in favour of the parasite's growth and development.

When one speaks of microbial parasites and their hosts, the broader theme into which the discussion could be subsumed is that of microbial cells interacting with one another or with other life forms. Such interactions may be achieved either through cell-cell contact or by diffusible compounds released into the milieu, and studies thereon have garnered much recent interest, which is reflected in the number of reviews covering such topics included in this volume. One example is the interaction between leguminous plants and bacteria of the genus *Rhizobium* to achieve biological nitrogen fixation and how type-III secretion systems of the bacterium modulate the symbiotic relationship. Another article examines the roles of secreted small molecules in three separate examples of microbial interactions, namely that between *Rhizobium* and legumes mentioned above, microalgal-bacterial interactions, and *Pseudomonas*-*Staphylococcus* competition in the lungs of children afflicted by the genetic disorder cystic fibrosis. One review describes the advances in our understanding of signal transduction processes during quorum sensing, which is the phenomenon (mediated again by secreted small molecules) by which bacteria display certain 'social' behaviours only when their population density in the culture crosses a threshold value. Another such social behaviour is that of biofilm formation, wherein solitary or sessile cells aggregate to form macroscopic mats or communities. Two articles in the volume are devoted to bacterial biofilm formation and its regulation in *Pseudomonas aeruginosa* (role of exopolysaccharide biosynthesis and degradation) and *Vibrio cholerae* (role of regulatory RNAs, transcription factors, and second messenger molecules such as cyclic-di-GMP).

It may perhaps be a truism to say that the principles of Darwinian evolution underpin all functions in various life forms, and several reviews in this volume dwell on various facets of these principles in the microbiological world. The concept of an 'evolutionary arms race' explains many features of host-parasite co-evolution, which is explored in one article on the evolution of tuberculosis pathogens, in another on bacterial defence against phage infections by employment of toxin-antitoxin systems, and a third on regulation by ubiquitin of host-pathogen interactions. The review on Toxoplasma-driven host epigenetic altera-

tions referred to earlier also falls into this genre.

Evolution (as an underlying principle) is also featured in several other reviews. One is on killer meiotic drive in fungi, wherein, anthropomorphically speaking, 'selfish' DNA sequences 'act' during meiosis to kill those spores that do not carry the said sequences. The second is a summary of the work on 'diversity-generating retroelements' discovered in a variety of organisms which act through a reverse transcription pathway of transposition to generate mutations in target genes. The third describes how, in fungi, proteins called sirtuins (involved in epigenetic gene silencing) can serve as rewiring points for organisms to evolve novel metabolic functions. The last two pertain to the archaea and refer respectively, to the evolution of methane-related pathways and horizontal gene transfer as a mechanism for genome evolution.

Three areas of current topical interest in microbiology are (i) diseases caused by fungi, (ii) the widespread problem of resistance to antibiotics and (iii) understanding of the 'microbiome', that is, the natural community of microbes in the soil, the mammalian gut, skin and other habitats. All of them are covered in different reviews in this volume, such as (i) on gut microbiome research related to translational potential in human health and disease, and to metabolic detoxification of toxins, (ii) on inter-species interactions for emergence and spread of antimicrobial resistance, and development of new antibiotics by manipulations of fatty acid biosynthetic pathways, and (iii) on different aspects of studies on fungi including identification of antifungal drug targets through genomics, antifungal vaccines, and a brief treatise on the genus *Malassezia*. An autobiographical sketch by Regine Kahmann also touches upon her work on a fungal pathogen of corn.

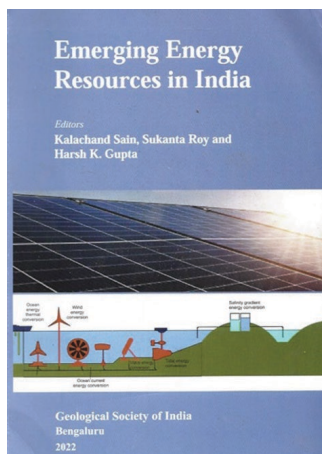
Finally, the volume also includes reviews on fundamental mechanistic processes within microbial cells, with the topics covering heterocyst formation in cyanobacteria, anaerobic degradation of alkanes by Archaea, oxygenases in pesticide degradation, biogenesis of bacterial ribosomes, the Omp85 superfamily of outer membrane transporters and assembly factors, and how polar flagella power motility of bacteria. Two of the reviews in this category are on the effect of RNA-DNA hybrids (R-loops) on genome integrity in bacteria and on the compartmentalized action of RNA degradosomes assembled on RNase E to mediate bacterial RNA degradation.

To conclude, historians of science would readily accept the idea that studies in microbiology in the decades of the mid-to-late-20th century had provided the underpinnings for not only the concepts of, but also appropriate tools for research in the discipline of modern molecular biology. Examples of such contributions from the microbiological studies have included (i) the identification of DNA as genetic material, (ii) establishment of the central dogma of molecular biology, (iii) elucidation of the mechanisms for regulation of gene expression, and (iv) development of methods for gene cloning, PCR, protein overexpression, and most recently CRISPR gene editing. It is no surprise, therefore, that these advances have, in turn, also been employed in studies of the microbiological world itself. The current emphasis is towards a better understanding of microbes not so much as solitary cells but as interacting partners within the larger biosphere, such as to exhibit social behaviours including those that are density-dependent (quorum sensing), or in biofilms, or as part of a microbiome, or in symbiotic or parasitic relationships with other host organisms. This focus is aptly reflected in the variety of articles in this volume.

1. Oren, A., *Philos. Trans. R. Soc. London B*, 2004, **359**, 623–638.
2. Alegado, R. A. and King, N., *Cold Spring Harb. Perspect. Biol.*, 2014, **6**, a016162.
3. Bar-On, Y. M., Phillips, R. and Milo, R., *Proc. Natl. Acad. Sci. USA*, 2018, **115**, 6506–6511.
4. Larsen, B. B., Miller, E. C., Rhodes, M. K. and Wiens, J. J., *Q. Rev. Biol.*, 2017, **92**, 229–265.

J. GOWRISHANKAR

*Indian Institute of Science Education and Research,
Sector 81, SAS Nagar,
Mohali 140 306, India
e-mail: shankar@iisermohali.ac.in*



Emerging Energy Resources in India. Kalachand Sain, Sukanta Roy and Harsh K. Gupta (eds). Geological Society of India, No. 30&31, B. P. Radhakrishna Bhavan, 1st Main, 3rd Cross, Byrappa Garden, Kathriguppe, BSK 3rd Stage, Bengaluru 560 085, India. 222 pages. Price: Rs 600.

At the 26th Conference of Parties of the United Nations Framework Convention on Climate Change, India updated its climate commitments. It stated that it will take its non-fossil energy capacity to 500 GW by 2030, meeting 50% of its energy requirements from renewable energy. By 2070, India plans to achieve the target of Net Zero (Ministry of External Affairs, 2021). In 2020, renewable fuel sources contributed a small but growing proportion of primary energy consumption (1%). The Geological Society of India has brought out a timely publication covering eight emerging energy resources which have the potential to meet India's expanding energy demands. Domain experts have comprehensively dealt with each of the energy resources.

Kalachand Sain has lucidly dealt with the fundamentals of gas hydrate energy resources. Methane in gas hydrates along the Indian margin had been estimated to be 1500 times more than the country's gas reserves. This large resource could bridge the supply–demand gap of gas in India and reduce carbon footprint. A brief description of the constituents of the Government of India's National Gas Hydrate Program (NGHP) is given. Success in the production of gas hydrates from Canada, the USA, China and Japan has given hope to the Asia-Pacific countries to produce this enormous energy resource. However, studies on critical parameters need to be carried out for gas hydrate resource development. Various geophysical techniques for evalu-

ating gas hydrate reserves have been identified. The production of gas hydrates is dealt with in detail. Production methods could be logistically challenging but could be replaced, initially by reservoir simulation. Readily available reservoir simulators can solve complex coupled processes for production. Though gas hydrates have been established in the Krishna–Godavari Basin, a concerted effort must be made to develop production methods suited to Indian offshore conditions.

Geothermal energy resources have been reviewed in detail by Sukanta Roy and Prafulla B. Sarolkar. Given the background of this energy resource, they have described the different types of geothermal energy resources as a result of the geology in areas of their occurrence. High-enthalpy resources found in volcanic regions and island chains provide the most efficient utilization of geothermal energy for generating electric power. Abundantly occurring medium enthalpy resources are sufficient to produce electricity in binary cycle power plants. The low enthalpy resources, abundantly found in most continental regions, are best suited for direct heating and cooling. A detailed history of hot spring mapping in India in the Himalaya, the Son–Narmada–Tapti (SONATA), West Coast, and Naga–Lushai provinces is presented. Key issues such as reservoir characterization are yet to be addressed in tandem with optimal utilization of the resource. A realistic assessment of the geothermal energy resources of India could pave the way for further research and technology development towards optimal utilization. Concerns about capacity building have been flagged.

M. Ravindran and G. A. Ramadass have contributed a well-illustrated chapter on Ocean energy resources – tidal or ocean thermal energy conversion (OTEC). As 70% of the earth's surface is covered by oceans, this renewable resource has enormous potential in various forms. India began its research on this energy resource in the 1980s and initiated installing shore-based plants on the islands and floating power plants along the main shoreline. Substantial progress has been made, and has crossed 20% share in renewable energy. The development of this energy resource is facing great challenges because of the high cost of the production plants and the cost of setting up offshore infrastructure. Reducing the cost of installation per MW production of electricity and increasing revenue from the plant could contribute to a brighter future for it.