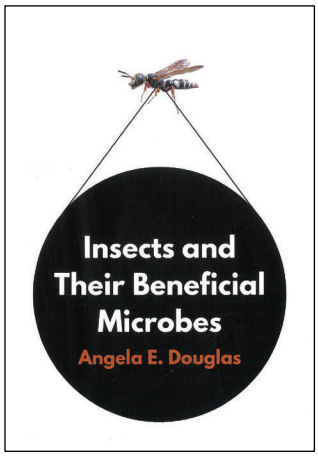
would find almost all the topics of his/her interest in this book. The description of topics is good enough to gain a basic understanding of the concept(s) and to prepare the student to delve into greater details in more specialized books or peer-reviewed research publications. While going through several topics in this book, I felt that they were like lecture notes that a teacher could easily follow in his or her class. The topics are covered without losing sight of the rigour and, at the same time, allotting optimal space to do justice.

This book takes on the herculean task of covering a large canvas as it touches upon topics and processes right from the surface of the earth to deep above into the earth's space environment. Such an effort is commendable. In some sense, it can be considered a treatise on earth's atmospheric structure and dynamics. It is a must-read for students pursuing their Masters or Ph.D. in atmospheric sciences and a must-have in the libraries of universities and institutes.

DUGGIRALA PALLAM RAJU

Space and Atmospheric Sciences Division,
Physical Research Laboratory,
Navrangpura,
Ahmedabad 380 009, India
e-mail: raju@prl.res.in



Insects and their Beneficial Microbes. Angela E. Douglas. Princeton University Press, 41, William Street, Princeton, New Jersey 08540; and 6 Oxford Street, Woodstock, Oxfordshire OX20 1TR, 2022. xiv + 330 pages. Price: US$ 39.95/£ 30.00.

In the burgeoning field of microbiome research, the study of insect microbiomes is making remarkable progress. Since Paul Buchner's fundamental work on unravelling intricate associations between insects and their microbial allies, the field has witnessed tremendous advancement. Over the years, technical advances coupled with the growing fascination for studying insects have uncovered the extraordinary might of tiny insects and their even tinier microbial partners. In her recent book *Insects and their Beneficial Microbes,* Angela Douglas provides an overarching, inside-out synthesis of our understanding of insects and their symbionts, stringing together a complex discipline filled with numerous model systems, approaches, outcomes, and applications.

Insects are an incredibly successful group of animals – their abundance, species richness and diversity in functional roles are unmatched. There are insects that feed on detritus, leaves, flowers, plant sap, animal excreta, blood, meat and even feathers. There are partially aquatic, terrestrial, and those that feed on different diets as larvae and adults. Within this bewildering diversity, the five major orders – Hemiptera, Coleoptera, Diptera, Hymenoptera, and Lepidoptera contain over 100,000 described species. One other life form that is spectacularly diverse, abundant, and functionally important is that of microorganisms. Reviewing these vast groups with dispersed literature, volatile taxonomies, and varying degrees of 'beneficial' interactions is no insignificant task. Therefore, a book that aims to document and describe beneficial associations between insects and microorganisms has a mammoth task. A task that Douglas accomplishes effectively through this lucid, instructive, and enjoyable book. Combining theory, specific examples, broad lessons, and stitching together commonalities and differences, the book provides an extensive overview of the past, present, and future of this emerging field.

One of the hallmarks of the book is a clear and logical flow of topics. Douglas carefully introduces the reader to the necessary concepts and terminology, providing a clear introduction to insect biology and possibilities for how insects can host and cooperate with beneficial microorganisms. There is remarkable diversity in how insects can associate with beneficial microorganisms. Douglas begins by classifying these associations as cases of ectosymbioses; describing the leafcutter ants, termites, and ambrosia beetles – the original inventors of farming who have been growing symbiotic fungi for millions of years; then considering the gut ecosystem, and the patterns and challenges involved in surviving and colonizing gut tissue, finally moving to endosymbioses – the most extreme form of symbioses where microorganisms reside inside specialized cells, organs or cavities in the insect.

The origin and maintenance of insect–microbe associations are central to the study of insect symbiosis. Exposure to myriad microorganisms through food, inter- and intra-specific contact, or the environment, the acquisition, and transmission of symbionts is a crucial aspect of these long-term associations. Parents, especially mothers, are important sources of beneficial microorganisms. In insects, parental care is not always present or is not as extensive as in higher animals, thereby limiting direct contact between mothers and offspring. Insect mothers have evolved complex and resourceful ways of transmitting microbes to their offspring. These involve symbiont transmission through egg surface, transovarial transmission directly through the germline, or through mature oocytes via somatic cells, viz. bacteriocytes, fat body cells, or those of specialized glands. Apart from the mother, insects can also acquire symbionts from other (conspecific) insects, a phenomenon often observed in insects across the social spectrum. Coprophagy (feeding on faeces) and trophallaxis (feeding on anal or oral fluids) transmit important beneficial microbes especially to younger, newly eclosed insects that do not acquire symbionts directly from their mother. Finally, many beneficial gut inhabitants in insects are acquired from their external environment, often through their diet, from parasitoids or during copulation. Douglas navigates the reader through these complex phenomena by providing a general framework and describing the mechanistic diversity in well-studied model systems such as *Drosophila* as well as in ants, bees, beetles, and other insects. Douglas describes how the host primarily controls the location, composition, and abundance of symbionts through specific immune factors and antimicrobial peptides, but also through broad strategies such as control of gut pH, oxygen tension, food availability, gut compartmentalization, and host development – specially during metamorphosis. Apart from host determinants, the book discusses how the prevalent microbial community can modulate the growth and colonization of incoming organisms. These can be cooperative, where the cross-feeding of metabolites produced by one group is further broken down by other members of the community, cumulatively benefiting the host by providing nutrition.

On the other hand, competition and predation across trophic levels, including viruses, bacteria, fungi, protozoa, and nematodes, can further affect gut community compositions.

At the heart of symbiotic interactions are the services that microorganisms provide to insect hosts. Many of these services are nutritional and protective. In plant-feeding insects, digestion of plant cell wall polysaccharides such as cellulose, hemicellulose, and pectin are normally outsourced to microbial symbionts. Douglas provides a detailed review of the problem and the solution to the breakdown of complex polysaccharides present within fibre-rich diets in termites, cockroaches, beetles, and bees. The other problem many insects face is nitrogen deficiency, where several phytophagous, xylophagous, and detritivorous insects rely on microbial symbionts for compensation or recycling of nitrogenous compounds. Providing sufficient background of methodological details, Douglas succeeds in providing a comprehensive overview of the how and why of symbiont-mediated amino acid synthesis, including the division of labour between insects and endosymbiont genomes in essential amino acid biosynthesis, their origins *via* horizontal gene transfer, and partitioning of these enzymatic steps between two or more microbial symbionts. Other nitrogen acquisition routes are also discussed, viz. nitrogen fixation, uric acid recycling, and microbial nitrogen harvesting. Besides providing essential nutrients and digestive enzymes, microbial symbionts contribute to insect defense by producing antimicrobials. Best-known examples of these include the beewolves and fungus-farming ants. Another important benefit that insects gain from microorganisms is the detoxification of plant secondary metabolites or dietary toxins. Our understanding of these associations, which have implications for crop ecology, comes mostly from herbivorous insects associated with ancient digestive symbionts that have shaped host adaptation to plant toxins. Additionally, insects have adapted to more recent environmental challenges where horizontally acquired microorganisms help insects detoxify organophosphate insecticides that farmers spray on crops. Here, Douglas carefully examines the available evidence to distinguish between host and symbiont mechanisms of detoxification.

Insects are, in many ways, the movers and shakers of terrestrial ecosystems. The later sections of the book are devoted to leveraging microbial symbionts towards managing insects as major agents of crop damage, disease transmission, and degradation of natural and managed habitats. Although the importance of microbial symbionts in managing insect pests has been recognized for a long time, a major challenge in its implementation has been the uncultivability of several symbionts. However, Douglas makes the key point that despite these limitations, the availability of modern sequencing and microscopy methods has provided a paradigm shift in not only our understanding of fundamental interactions between insects and symbionts but also in harnessing their untapped potential in addressing real-life problems. The book delves into success stories, primarily dealing with mosquito research and agricultural pests in the context of *Wolbachia*-induced cytoplasmic incompatibility. A promising and exciting section of the book is where Douglas reviews avenues of introducing genetically modified microorganisms in insects to attenuate insect damage or suppress insect-vectored pathogens. The book also provides a succinct summary of prerequisite methodological details that helps place the results of complex experiments within context. The book combines diversity in experimental approaches and insect taxa to comprehensively assess the current state and future promise of this research discipline. Finally, Douglas extends this spectrum of leveraging symbionts for insect management to their application in human health and biomedicine. This is based on the value of *Drosophila* as a biomedical model organism, given the wealth of genomic resources available, the possibility of creating axenic flies and the prospect of using these findings to better understand human diseases and disorders. The book draws important links between *Drosophila* microbiome research and its applicability in human ageing, immune function, nutrition, Alzheimer's disease, and social behaviour.

Reading the book is no less than being on a safari that showcases the wonders of the insect world through the eyes of an expert researcher and a wonderful writer. The journey is filled with spectacle, leaving the reader with awe for the incredible ingenuity of insects, admiration for the power of natural selection, and an overview of methods of enquiry in this discipline. Young, budding entomologists, microbiologists, and ecologists will take inspiration, and for those already pursuing these questions, the book offers perspective. For everybody else, this book is an incredible compendium of insight and information, a ready reckoner that is a delight to read. A book that the readers will undoubtedly keep in the closest and most accessible part of their bookshelf.

SHANTANU P. SHUKLA

Developmental Biology and Genetics,
Indian Institute of Science,
Sir CV Raman Avenue,
Bengaluru 560 012 India
e-mail: sps@iisc.ac.in