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Editorial: Coevolution of insect-gut microbiome

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Editorial on the Research Topic
Coevolution of insect-gut microbiome

Dimijian (2000) stated that "Symbiotic relationships exist everywhere we look; they are beginning to seem like the very essence of biology." To be sure, the involvement of symbiotic associations and symbiogenesis provide profound biological influence. Examples include the emergence of new structures such as from the partnering of algae and fungi (lichens), the bioluminescence provided by *Vibrio fisherii* to the Hawaiian Bobtail Squid, nitrogen fixation, and the discovery of the photosynthetic Yellow Spotted Salamander. Thus, symbiotic pairings do appear to be an intrinsic driving force contributing to the diversity of life, the successful existence of many species, immune and other physiological processes, and the very essence of biology.

When one thinks of successful species on Earth, insects and microorganisms undoubtedly come to mind. The origin of insects appeared approximately 479 million years ago during the Early Ordovician (Misof et al., 2014) and are considered to be the most successful animals, accounting for > 90% of known animals, and whose natural history is endowed on associations both internally and externally with microorganisms (Douglas, 2014). Classic examples include termites and gut cellulolytic bacteria, *Sitophilus* beetles and their endosymbiont (SOPE, *Sitophilus oryzae* endosybiont) and flight, leaf-cutting ants and symbiont cultivation, and *Wolbachia* causing an array of effects such as feminization, parthenogenesis, cytoplasmic incompatibility, and viral defence. More recent examples include the potential role of symbionts in insecticide resistance (i.e., Pietri and Liang, 2018), a *Burkholderia* sp., ectosymbiont that has been shown to protect *Lagria villosa* during molting stages (Janke et al., 2022), sleep-promoting effects of human intestinal bacteria provisioned to *Drosophila melanogaster* (Ko et al., 2023) and Mosquera et al. (2023) who provide data suggesting that the bacterium *Elizabethkingia* exerts a positive effect on the development and fitness of mosquito larvae. And these are just a few.

The earliest fossil evidence for life on Earth is bacterial (Alegado and King, 2014), with indications that bacteria may have been present during the Precambrian (i.e., Astafieva and Rozanov, 2012) much before the origins of animals some 2 billion years thereafter. Bacteria reshaped the planet giving rise to new environments, atmospheres, and climates, shaping habitats, life, and weather patterns. Associations became inevitable as bacteria sought resources, shelter, and niches, even within other bacteria (Sagan, 1967; Margulis, 1996). Invasions led to adaptations (Margulis, 1996; Moran, 2007), horizontal gene transfer shaped genome complexity (Emamalipour et al., 2020), and diversity resulted. For bacteria, acquired complexity includes behaviors and communication, such as altruism (i.e., Shub, 1994) and combat (Basler et al., 2013), respectively. Given the long evolutionary history between arthropods and microorganisms, it is logical to infer that their associations have contributed to or been the cornerstone for both arthropod and microbial success.

This Research Topic presents varied relations between arthropods from several taxonomical groups and their microbiota. Historically, arthropod-bacteria studies focused on bacterial odors as attractants to food sources or host plants and pathogen transmission and involved primarily culture-based methods. Most newer studies regarding insect microbiota and associated microbiomes utilize more advanced techniques and characterize bacterial communities' structure within an insect or its immediate environment and how such communities change depending on different environmental conditions. In this Research Topic, Kumar et al. describe and discuss the diversity and structure of gut bacterial communities associated with seven spider species belonging to two families of spiders. Although this is a prerequisite for understanding the associations between insects and microorganisms, the ecological and behavioral significance of such interactions is often undefined, and integration of the existing knowledge is lacking. To bridge this gap, Kumar et al. offer a bioinformatics analysis to predict the metabolic impact of the bacterial communities found in spiders. Although bioinformatics tools are robust and may point us in the right direction, *in vivo* and *in vitro* demonstrations of the implications of bacterial communities residing within or in the insect's immediate environment to the insect's fitness and the ecosystem are crucial. The review by Sela and Halpern is a beautiful example of such a demonstration. This article presents an in-depth classical biological study of the chironomid microbiome's different roles during its host development and its effect on larvae growth. Another excellent example of the microbiome effect on insect host fitness is the study conducted on termites. The microbiome of termites has been studied extensively since the early 70s of the last century. Nevertheless, the study by Chen et al. in this Research Topic presents new and intriguing insights into various interactions that are taking place within the termite gut. This article describes how viruses, bacteria and protozoa co-evolved, affect each other and ultimately affect their host.

As the scientific community continues to explore the associations of microorganisms between and among each other and in partnerships with arthropods and other hosts, findings will assuredly offer a bidirectional avenue for understanding the "essence of biology" and highlight microorganisms as the ultimate influencers. As such, and stated perfectly by McFall-Ngai et al. (2013): "[all] biologists will be challenged to broaden their appreciation of these interactions … as we seek a better understanding of the natural world." The collection of work within this Research Topic advances our knowledge and appreciation of microorganisms as intricate and major contributors to arthropod life.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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