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Editorial: Women in coevolution 2022

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Editorial on the Research Topic
Women in coevolution 2022

While women have been and continue to be underrepresented in science (World Economic Forum, 2023; UNESCO, 2024), they have been integral to advancing the field of evolution as well as the subfield of coevolution, the topic of this thematic collection of articles. Since natural selection was first theorized, Charles Darwin illustrated the selection pressures imposed not only by the environment, but also by interactions between species resulting in reciprocal evolution, i.e. coevolution. In particular, he famously predicted the existence of a species of moth that must possess an unusually long proboscis to obtain nectar at the end of the long floral spur from the orchid *Angraecum sesquipedale* (Darwin, 1862, pp. 197-203; Arditti et al., 2012). Indeed, the moth predicted to pollinate *A. sesquipedale* does in fact exist, formally described in 1903 as *Xanthopan morganii praedicta*, thus demonstrating the predictive power of coevolutionary theory (Arditti et al., 2012). Systemic biases, however, have led to research in evolution to be largely dominated by men (Wellenreuther and Otto, 2016), and consequently, the topics or ideas that have been investigated have also been tackled through a male-biased lens (Keller, 2004; Ah-King, 2022).

Despite the historical lack of opportunity, resources, and recognition, women have made outstanding contributions to coevolution. A female pioneer in this field is Lynn Margulis. She revived the symbiogenesis theory, that organelles such as mitochondria and chloroplasts are descendants of free-living independent prokaryotes that evolved reductively, to become obligate intracellular symbionts (endosymbionts) of a proto-eukaryotic cell (Sagan, 1967). Initially, the theory, based on physiological and structural evidence, was widely rejected, but Margulis's intuitions on an endosymbiotic origin were eventually proven with the added support of genetic evidence (Schwartz and Dayhoff, 1978; Gray and Doolittle, 1982). This episode opened our minds to the expanse of possible paths that evolution can take.

In keeping to our theme, transformative actions supporting women in science will also contribute towards a positive coevolution between genders in our societies, requiring all genders to work cooperatively, and reciprocally, to explore and find solutions for the critical challenges impacting our collective futures, such as climate change and sustainable resource use (Nature editorial, 2022; Yang et al., 2022). The voice, actions and thoughts of women in science are needed for the evolutive success and happiness of humankind.

In this Research Topic in *Frontiers in Ecology and Evolution*, we move the field of coevolution forward by bringing attention to research spearheaded by women, who continue to break new ground by exploring the diversity and complexity of factors that contribute to coevolution and the implications of this type of evolution.

There has been tremendous growth in the field of coevolution for the last 60 years, with many women pushing these advances forward. In the inaugural contribution, Medina et al. incorporate the views of the editorial board to describe the next frontiers in coevolution as an open call to spark progress in the field and highlights areas of active research. In particular, technical advances and bioinformatics have opened up new possibilities in characterizing microbiomes and viromes including those that are host-associated. However, these advances also lead to greater complexities because of the increased awareness that animals and plants do not live in isolation, but rather live with (or host) many microorganisms. Medina et al. also broaden the definition of coevolution to reciprocal interacting lineages rather than species.

Since Margulis' revival of the endosymbiotic theory, microbe-metazoan symbioses have been recognized as evolutionary engines, creating metaorganisms with higher capacities to adapt and colonize an array of environments (Margulis and Fester, 1991). Díez-Vives et al. elegantly review symbiont acquisition and transmission mechanisms in sponges (phylum Porifera). These fundamental microbial partnerships are vertically transmitted across generations in a variety of modes into oocytes, sperm, embryos, and larvae. Indeed, Porifera represent optimal models for coevolution studies, since they lack a determined germline, and exhibit diversified reproduction strategies (Riesgo and Solana, 2021). Inherited microbes may remain viable and provide metabolic exchange by "milking", or be digested for nutrient reserves (symbiont farming). But sponges may as well acquire symbionts from the water column (Taylor et al., 2007). A combination of horizontal and vertical transmission shapes sponge mature microbiomes, with the key participation of immune recognition, and environmental adaptation.

Another iconic coevolution relationship in aquatic ecosystems, is reef-building corals and their endosymbiotic dinoflagellate microalgae (Symbiodiniaceae). Ruth Gates, the British coral biologist and activist, left an inestimable legacy in her knowledge of the complexity and diversity of coral symbioses (Gates and Ainsworth, 2011), preservation of reefs via human-assisted evolution (van Oppen et al., 2015), and in her mentorship of early scientists. As with sponges, these algal symbionts are essential for fitness and reproduction success, and can be inherited across generations and/or acquired horizontally (LaJeunesse et al., 2018). In healthy corals, 100% of the carbon budget and some nitrogen can be derived from photosynthates (Muscatine et al., 1981), while heterotrophy supplements carbon and nitrogen resources (Hughes et al., 2010; Ferrier-Pagés et al., 2011; Krueger et al., 2018). These functional symbioses are sensitive to ocean global warming, leading to coral bleaching episodes as temperature rises. This entails the loss of symbiotic algae and photosynthetic pigments, and consequent loss of photoprotection and energy for the coral holobiont (Grottoli et al., 2006). In building on these discoveries, Jaffe et al. used a time-series experiment mimicking bleaching patterns in Hawai'i (Bahr et al., 2017), and assessed the transfer of autotrophic and heterotrophic carbon and nitrogen to developing eggs and gamete bundles in non-bleached and previously bleached (manipulated) *Montipora capitata*.

In plant-pollinator coevolution, some interactions have evolved so tightly that both pollinator and plant are exclusively dependent and specialized on one another, whereas other relationships are more flexible and the species are generalists. Burns et al. tackle the fitness consequences of interactions with generalist versus specialist pollinators of plants. The motivation was to investigate whether the effect of disturbances, which may become more frequent with climate change, can be buffered by generalists because specialists will be less able to adapt to the more varied conditions caused by disturbances. They tracked insect pollinators using innovative camera observations, as well as experimentally tested the contributions of generalists and specialists to seed and fruit output, in particular with *Rubus arcticus*, an Arctic raspberry species.

A long-observed example of antagonistic coevolution is the common cuckoo and its host. The common cuckoo is a frequent obligate brood parasitic bird in Asia and Europe. In the Yongnianwa National Park of China, the common cuckoo lays its eggs in the nest of the oriental reed warbler resulting in about ~15% of nests becoming parasitized (Ma et al., 2018). Nestling begging calls are essential for communication between the nestlings and parents but louder and more visible begging behavior carries greater risk of predation. Wang et al. use recordings of warbler alarm calls to evaluate this tradeoff and the coevolution between parent-offspring, and found similar begging behavior between cuckoo and host nestlings.

Finally, theoretical assumptions and predictions of coevolution were experimentally tested in the article by Vidal et al. A fascinating set of yeast experiments was conducted to test the role of coevolution in the persistence of mutualistic interactions when a third party, an exploiter, siphons off a mutually exchanged resource which breaks down the mutualism. By engineering yeast strains for a specific role (mutualist or exploiter), Vidal et al. test several factors that have been theorized to weaken mutualisms, such as the level of dependence between mutualistic partners or the presence of exploiters. Furthermore, they explore how coevolution contributes to the resistance of exploitation due to a tighter interaction between mutualists, but also the persistence of exploiters, due to exploiters coevolving alongside mutualists where they may evolve to contribute a common good.

This woman-led collection of journal articles encompasses many aspects of coevolution to inspire all researchers and in particular girls and women. Because we believe that gender diversity enriches science and the scientific community, we hope this Research Topic will lead to increased support for women in science.

Author contributions

LN: Conceptualization, Investigation, Validation, Writing – original draft, Writing – review & editing. VT: Conceptualization, Investigation, Validation, Writing – original draft, Writing – review & editing. MR: Conceptualization, Investigation, Validation, Writing – original draft, Writing – review & editing.

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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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Publisher's note

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