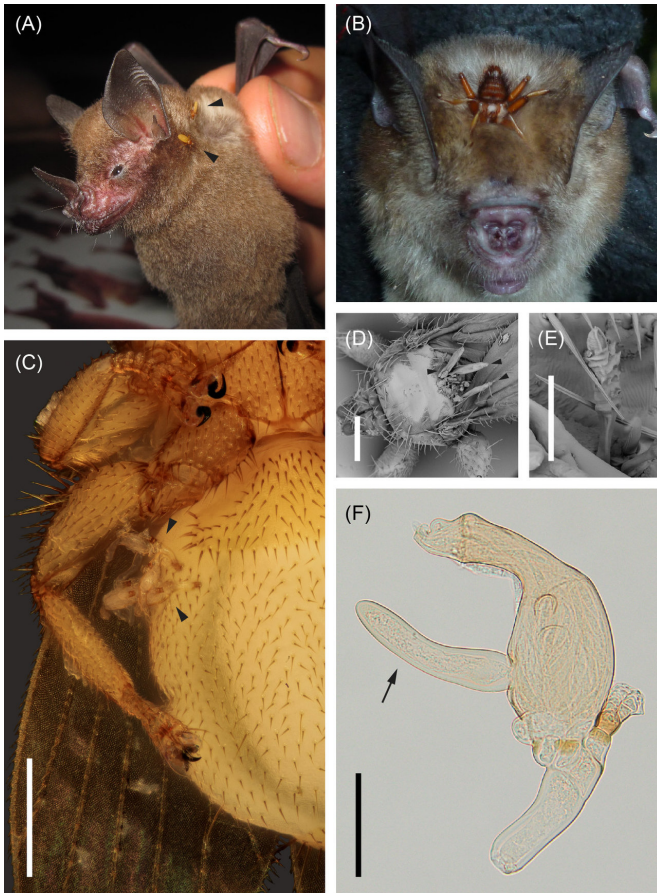


# My host is my castle—bats as hosts

8 August 2018



(A) A *Carollia perspicillata* bat with two *Speiseria ambigua* bat flies (arrowheads), captured at La Virgen de Sarapiquí, Costa Rica. (B) A bat of the *Hipposideros caffer/ruber* complex with a single *Penicillidia* sp. on its head, from Forikrom, Ghana. Image provided by Julian Schmid. (C) *Trichobius joblingi* (from *Carollia perspicillata*), with thalli of an undescribed species of *Gloeandromyces* on its abdomen (arrowheads). Image provided by André De Kesel. (D-E) *Trichobius costalimai* (from *Phyllostomus discolor*), with thalli of *Nycteromyces streblidinus* on its thorax, from Peña Blanca Peninsula, Panama. Scanning electron microscopy images provided by Alena Maidel. *Nycteromyces* is dioecious, which means that (male) antheridia and (female) perithecia are housed on separate individuals. (D) Three female thalli are indicated by arrowheads. (E) Close-up of a single male thallus, forming antheridia that produce spermatia. (F) *Gloeandromyces* sp. nov., recognized by its finger-like projection at the perithecium (the spore-producing organ) and supported by sequence data

(referred to as *Gloeandromyces* sp. nov. 3 in [8]). Scale bars: (C-D) = 250  $\mu$ m, (E-F) = 50  $\mu$ m. Credit: Danny Haelewaters, Harvard University, The Department of Organismic and Evolutionary Biology

Despite researchers having little fondness for them, a large fraction of the world's biodiversity consists of parasites. Natural populations of organisms are often strongly affected by factors of their environment, most notably the effect of predators. Yet, the most outstanding arms race, produced by millions of years of coevolution, is seen between parasites and their hosts. Bats, the second-most diverse mammal order worldwide, are parasitized by numerous lineages of arthropods; bat flies are the most conspicuous. In turn, bat flies themselves can be parasitized by Laboulbeniales, fungal biotrophs of arthropods. This example of hyperparasitism—a condition where a secondary parasite develops within or on another parasite—of bats, bat flies and fungi, is a severely understudied phenomenon.

In a new paper in *Trends in Parasitology*, researchers Danny Haelewaters, Harvard University, Carl Dick, Western Kentucky University and Thomas Hiller, the University of Ulm, review what is known about the tripartite study system with bats, bat flies and fungi. Known are a few reports from the early 20th century, two more in 1980, and then relatively nothing until 2017, when some studies revealed many new hosts, [host](#) associations and undescribed taxa, hinting at a much larger diversity of these unique fungi than currently known. "Only about 10% of Laboulbeniales species parasitize flies," says Haelewaters. "The genus is by far the largest with hundreds of species, of which only 24 species are on flies."

The lack of study of hyperparasitism raises several underexplored questions: How did such associations evolve? What population limitations are necessary to maintain these relationships? How

strict are the species-level relationships? In their review, the team pointed out that we know virtually nothing about the biology, host associations or phylogenetic relationships of the different organisms involved. This tripartite system involving bats, bat flies and Laboulbeniales fungi is intriguing and ripe for future study. Hiller says studies on biodiversity rarely include the associated [parasites](#), missing out on important information on host population and ecosystem health. "Host-parasite-systems, like this tripartite association, are often complex and studies on host as well as parasite ecology are crucial for correct interpretations of mere species lists'

The production of robust phylogenetic reconstructions for both bat flies and Laboulbeniales on a global scale is critical to future studies of the ecology, evolution and co-evolution of this tripartite system. "Studies in hyperparasitism lay bare the fact that the natural world remains underexplored," explains Dick. "Our understanding of hyperparasites pales in comparison to our knowledge of parasites, which in turn pales in comparison to our knowledge of hosts." In addition to patterns and processes in ecology and evolution, studies in this and other multi-tiered systems will advance the continued discovery of true global biodiversity. "No one has looked at these organisms in the field in about 100 years," says Haelewaters. "We have gone to the Darien Gap in Panama to study this tripartite system in a small reserve and yet we found three undescribed forms and new findings for the bats and bat flies. Even after the Golden Age of discovering, naming and organizing a tremendous amount of biodiversity back in the 18th and 19th centuries, we are still exploring."

Large field surveys and well-curated museum collections will help produce a database of tens of thousands of bat flies, which can be searched to find associations between parasitism by Laboulbeniales on the one hand and ecological and life history traits of bats and bat flies on the other. Such comprehensive datasets can provide insight into broader-ranging questions, such as how habitat disturbances can shape symbiotic relationships.

**More information:** *Trends in Parasitology*, Danny Haelewaters, Thomas Hiller, Carl W. Dick: "Bats, bat flies, and fungi: A case of hyperparasitism" [DOI: 10.1016/j.pt.2018.06.006](https://doi.org/10.1016/j.pt.2018.06.006)

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