

**Overview:**

One universal feature of the Tree of Life is that diversification rates vary widely among lineages and over time. Key innovations, such as changes in life history, may be one explanation for dramatic shifts in diversification. In insects, shifts in diet, especially shifts from carnivory to herbivory, shifts in sociality, especially the transition from solitary nesting to eusociality, and shifts from a free-living to parasitic life style, have all been implicated in diversification rate shifts, both positive and negative. Few lineages of insects include taxa that exhibit all of these life history traits, making it difficult to compare the impact of these factors on diversification within a closely related group of organisms.

The stinging wasps and bees (Aculeata) represent one such lineage because aculeate taxa exhibit a diversity of life histories and multiple shifts in life history. The transition from carnivory (parasitism and predation) to pollenivory has occurred twice in aculeates: once in the common ancestor of the bees and once in the common ancestor of the vespid wasp subfamily Masarinae (pollen wasps). Eusociality has arisen repeatedly within bees, in the common ancestor of the ants, and between one and two times within the wasp family Vespidae. Finally, cleptoparasitism has arisen repeatedly within Aculeata from within bees as well as predatory wasps (Crabronidae, Pompilidae, and Sapygidae). How these shifts in life history have impacted diversification is unclear because of uncertainty about higher-level relationships among aculeate taxa.

**Intellectual Merit:**

We will reconstruct phylogenetic relationships among Aculeata based on genome-wide molecular data sets constructed from enriched libraries of over 700 ultra-conserved elements (UCEs). These phylogenies, in combination with the diverse fossil record for Aculeata, will be used to construct fossil-calibrated trees and to assess the impact of life history on diversification. Preliminary analyses of UCE data sets indicate that these methods are extremely powerful for reconstructing relationships within Aculeata.

Our primary goals include the following:

1. Determine whether shifts from carnivory to herbivory (pollen feeding) have led to increased diversification by identifying the sister group to both the bees and the pollen wasps.
2. Test whether shifts in social behavior have impacted rates of diversification by establishing the phylogenetic relationships among the Vespoidea, in particular identifying the sister group to the ants and the phylogenetic relationships among the vespid wasp subfamilies.
3. Determine whether shifts from brood provisioning to open-celled cleptoparasitism leads to increased diversification in cleptoparasitic taxa by establishing the phylogenetic relationships among cleptoparasitic groups, including Sapygidae, cleptoparasitic Pompilidae, and cleptoparasitic Crabronidae, and their non-parasitic relatives

**Broader Impacts:**

The proposed work will have extensive broader impacts in training, data dissemination, and outreach/public education.

1. Training: The project will result in training for undergraduates, graduate students, and post-docs in a highly integrative and collaborative research environment. These participants will be aggressively recruited from under-represented groups.
2. Data dissemination: Significant amounts of publically accessible data will be made available through Genbank, TreeBase, Dryad, and EOL webpages. Wet laboratory and software pipelines will be made available to the broader scientific community.
3. Public outreach/education: Our project will lead to the development of a 600 square foot traveling public exhibit on the biodiversity, evolutionary history, and fossil record of bees and related wasp groups. The exhibit will be developed in collaboration with the Paleontological Research Institute (PRI) in Ithaca, NY, which has two public science education facilities (the Museum of the Earth and Cayuga Nature Center) and which produces exhibitions and educational programming for both local and national audiences. PRI will handle exhibit marketing, scheduling, and travel for the full three years of the grant.