OVERVIEW

A main tenet of the Darwinian Revolution, made orthodoxy during the Modern Evolutionary Synthesis, is that macroevolution is merely microevolution 'writ large'. That is, extended over long periods of time, the gradual action of natural selection over generations resulted in the broad patterns of diversity observed today. However, a small but vocal group of evolutionists, paleontologists, and philosophers have challenged this orthodoxy, claiming that Darwinian processes acting on generational time scales have less power to explain long-term evolutionary patterns than do contingency, constraint, and chance. Testing these competing ideas against one another is difficult because the time scales over which we would like to track evolution are longer than we can typically access with experiment and observation. That is, we either observe evolution for as long as we can and extrapolate forward, or we observe evolutionary endpoints and infer backwards. Both approaches are missing data: the intermediate evolutionary trajectory. Here, we address this knowledge gap using a museum collection from a high-resolution fossil deposit of the Threespine Stickleback fish (*Gasterosteus doryssus*). We observe evolution with a continuity, resolution, and length of time rarely available in studies of extant or extinct species. We will track adaptive and non-adaptive evolution across 20,250 years to ask seven questions about rates of short- and long-term change, evolutionary trends, the role of trait correlations during adaptation, and the shape of adaptation itself. As such, this work will reveal whether and how short-term evolutionary changes contributed to long-term evolutionary change in this stickleback lineage.

INTELLECTUAL MERIT

We propose to observe evolution directly, rather than infer its tempo and mode between endpoints, making for stronger tests of the relationship between short- and long-term change. Because we are following a single lineage through time, the ancestral form is known, rather than inferred. Thus, we can better ask how selection shaped evolutionary trends, how ancestral trait correlations constrained evolution, and whether constraint itself evolved. This system has the important, added strength of involving a member of a clade (the stickleback) whose evolution, ecology, genetics, and development have been thoroughly studied in extant populations. As such, we can place observed phenotypic change in *G. doryssus* into a broader biological context to make richer inferences about evolutionary process and whether macroevolution is microevolution write large.

BROADER IMPACTS

Fossils show evolution directly in a manner accessible to students. The broadest impact of this work will be the incorporation of these fossil data into two new courses to be developed by the PI. The courses will use modern pedagogical tools to teach evolution, quantitative reasoning, history of science, and technical writing to biology and non-biology students. Open-inquiry analysis of fossil data during activities will help instill those key concepts. The courses will contribute to Loyola University Chicago's (LUC) Writing Intensive and CORE programs, a key mission of the Biology Department. Course development will also enhance the PI's existing courses. As such, the PI will train ~150 students per year toward a well-rounded scientific education. The PI will reach students outside of LUC by making his lessons and data available on education websites.

This proposal will train a postdoctoral scholar in research, mentorship, and project management, and provide professional development as they purse STEM careers. The project will provide funded research experience for 4 undergraduates and volunteer opportunities for more.

Moreover, by researching these fossils, we will speed the digitization, databasing, and permanent housing of a rare and valuable collection, making it more visible and more accessible to the scientific and educational community. We will also build a public web repository, making all data in this system accessible for new collaborations, research, and curriculum development.