PROJECT SUMMARY

Overview:

A primary aim of geobiology is to understand how geo-climatic processes shape evolution and biodiversity on Earth. A wide range of tectonic and climatic processes are known to govern landscape evolution, yet the potential for biological evolution to be driven by co-occurring processes (pseudocongruence) is often overlooked. Systemic failure to consider pseudocongruent processes can lead to misinterpretation of the fundamental cause-effect controls on Earth-life evolution. Using a diverse suite of geologic and genomic data, Dorsey et al. aim to identify individual effects by testing multiple non-mutually-exclusive hypotheses on the central Baja California peninsula, Mexico (BCP), which hosts a well-known site of intra-specific genetic divergence with an unknown origin. The team will collect geologic data to characterize and date Earth surface processes operating since 6 Ma, and generate extensive population genomic and gene expression data for six disparate species. The project will test three hypotheses: (1) populations were isolated by a physical barrier (marine seaway) in the mid-peninsular region; (2) Pleistocene glaciations isolated populations in refugia; and (3) monsoon-driven differences in rainfall timing isolated species through asynchronous reproduction and/or differential adaptation to precipitation regimes. The BCP is an ideal setting for this work because its geo-climatic processes can be well characterized in space and time, and each hypothesis yields a clear, testable evolutionary prediction. The team will map and date structural, stratigraphic, and volcanic features in the mid-peninsular region where the divergence occurs; use state-of-the-art geochronologic methods to constrain the history of deposition, deformation and uplift; evaluate low-coverage genomes of angiosperms, reptiles, mammals for population genomic signatures, loci driving local adaptation, and patterns of allelic variation over space; test seasonal differential gene expression; develop niche models under modern and glacial climates; and test for present-day niche divergence. Additionally, the team will use multi-species approaches to test for cross-species divergence patterns, constrain genomic models with geologic data, and assess how information theory can be applied to genomic data to decompose the effects of evolutionary pseudocongruence.

Intellectual Merit:

The cross-disciplinary framework of the proposed study will lead to four major intellectual advances. First, this project will embrace geo-climatic complexity to explore how multiple extrinsic factors can drive genome evolution and diversification. Second, the study uses a novel combination of complementary geological techniques within an evolutionary framework -- integrating organismal genomic evolution with the concurrent evolution of the physical environments -- to demonstrate how the approach can be applied to other systems. Third, the results will advance understanding of forces that have driven synchronous intraspecific divergence in an area known for its high endemism levels and complex tectonic, volcanic, and climatic development. Fourth, the results of this research will provide an important first step toward developing more predictive models of Earth-life evolution that can be applied to deeper timescales and in other systems (e.g., potentially other planets).

Broader Impacts:

This project will promote the research of two women PIs, one of whom (Dolby) is an early career scientist developing a synergistic geogenomic research program. The work will include collaboration with Mexican scientists and will be coordinated with two other studies in central Baja California that are currently funded by NSF. PIs will mentor and train three postdoctoral researchers, five graduate students, and many undergraduates in an interdisciplinary framework that integrates sedimentology, tectonics, volcanology, evolutionary genomics, bioinformatics, geochronology, computer animation, and science education. The team will create a series of short educational videos demonstrating tools and techniques common in fieldwork, and a set of animations to summarize the geobiological history of the Baja California peninsula to teach interdisciplinary concepts to non-specialists. Dorsey et al. will make a free repository for all data products to aid researchers developing new pseudocongruence analytical tools, and the website will also host information on how to implement large interdisciplinary projects (e.g., meeting schedules and formats, guidelines for integrating cross-discipline techniques, etc.). Finally, the PIs will host a grant-funded community workshop to advance Earth-life research, and implement an art-science collaborative course between Arizona State University and University of Arizona.