IBI* SERIES WINNER

Investigating Arabia Mountain: A Molecular Approach

"Investigating Microbial Diversity on Arabia Mountain," the IBI Prize–winning module, allows students to explore microbial diversity by DNA isolation and sequencing.

Nitya P. Jacob

Exposing undergraduate students to inquiry and discovery, elements that lie at the core of science, is an effective strategy to lure them into the scientific world. This is typically accomplished when individual students partner in research with a faculty member on an independent project. However, such opportunities to participate in research are limited to a small number of students in their third and fourth years of college. Ideally, all students should begin their journey into the world of scientific discovery as early as possible.

Teaching at Oxford College, an undergraduate division of Emory University focused on the liberal arts education of first- and second-year students, gave me the inspiration to lead such a journey. I designed a research module, Investigating Microbial Diversity on Arabia Mountain: A Molecular Approach, for the laboratory component of Biology 142: Advanced Topics in Genetics and Molecular Biology, the second course in our introductory biology curriculum. The first course, Biology 141: Cell Biology and Genetics, establishes basic foundations of research in the laboratory: learning general techniques, repeatedly applying the scientific process, researching literature, and practicing written and oral scientific communication, through a variety of exercises (*1*). Taking students to a new level of being actively involved in an authentic research experience in the second course became the natural next step.

A unique feature of the local Georgia landscape is the presence of several exposed granite rock outcrops, the most famous being Stone Mountain. Plant communities, ecological succession, and evolution of these granite outcrops have been studied in detail over many years, by a series of Emory University biologists (*2*, *3*). However, not much is known about the microbial ecology in this ecosystem. Exploring the extent of microbial life on the planet has recently come to the forefront of biology (*4*). The topic of investigating microbial diversity on Arabia Mountain, a granite rock outcrop near Oxford, Georgia, provides an opportunity to use the tools of molecular biology in an ecological setting, an approach used in current studies (*5*) (see the photos).

Arabia Mountain, Lithonia, Georgia. Students collect samples from a variety of environmental niches dispersed in depressions on the exposed rock outcrop surface.

The 11-week laboratory research module has four components: thinking time, field experience, laboratory bench work, and communication. Thinking time is the most essential element of this module. In a class of 24 students, six research teams of three to four individuals each design an original research question under the broad umbrella of investigating microbial diversity in the environment of a granite rock outcrop. Students research existing literature on microbial and plant ecology during a scheduled laboratory period. The instructor and a librarian check in periodically with each group to provide guidance as needed. Linking this module with a long-standing collaboration between the Biology department and the library was central to achieving information literacy learning goals throughout the project (*6*). After consulting scientific literature and active collaborative discussion in the classroom, each research team writes a proposal presenting a specific research question and a corresponding hypothesis with a well-substantiated rationale. The research questions posed by each group are shared with the entire class and the instructor helps teams to establish a common connection between individual questions, enabling each team to later analyze their data in the context of discoveries made by other teams in the same class. The laboratory module continues with field experience at Arabia Mountain where soil samples are collected onto nutrient agar plates from various locations according to specific research questions.

In the 6 weeks that follow, research teams combine laboratory benchwork and thoughtful analysis to select morphologically distinct bacteria from their collections, amplify 16*S* ribosomal DNA (rDNA) from genomic DNA by the polymerase chain reaction, conduct restriction fragment length polymorphism analysis, and analyze 16*S* rDNA sequences with software tools (sequencing is completed at an off-campus facility)—all techniques that are new to them in this course (*7*, *8*). Thinking time continues in weeks 7 to 9 of the module when students examine and synthesize their data by actively discussing outcomes and arguments, with easy access to the instructor as a resource. In data synthesis, each student team also examines data generated by other teams, shared on the course's Blackboard Web site, to make final conclusions about their results (see the photo, page 1589).

Finally, in the communication component of the module, each team of students presents their project to the class in a research seminar format. Additionally, each student writes an individual paper on the project in scientific manuscript style.

The creative process of designing the question and later thoroughly analyzing the data as a group and as an individual is completely owned by the students. There is less flexibility in the experimental design of the

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laboratory procedure for practical reasons, such as the level of student experience and laboratory preparation constraints for an introductory course. Results generated by student projects provide preliminary findings on microbial community structure in outcrop soils. Projects have then been continued as independent research by students who have presented posters at summer research and regional society meetings and whose work is being prepared for publication. Another valuable outcome is increased interest and participation of our students in summer undergraduate research programs nationwide.

Understanding and testing the feasibility of the project with first- and second-year students required adjustments over several semesters since launching this module for the first time in 2006. A major challenge for students is the frustration and uncertainty that they are faced with at various points in the project.

Frustration begins in the very first week of the module. There are no existing publications specifically on the microbial diversity of granite rock outcrops in Georgia, and students expect to find direct answers in the literature while constructing a hypothesis. For example, connecting information from published studies on soil bacteria to propose a hypothesis about bacteria living in outcrop soils is not an easy task for them. While analyzing data, students struggle with making sense of information. They often find unexpected results, not consistent with their hypothesis, such as a lower level of bacterial diversity than expected or finding bacteria with variable morphological forms identified as the same species by DNA sequence analysis. Synthesizing the data of other teams for a comparative analysis in their report is also a difficult exercise. Overcoming these challenges requires the instructor and students to work together as true partners in scientific discovery. The instructor should be prepared not to have all the answers for the students, but instead should ask the right questions to help them move in a positive direction.

The rewards of getting through this challenging process come at the end of the semester. Students learn that research is not straightforward and outcomes are often unexpected. When pushed into an uncomfortable space with unexpected research results, students learn to think deeper to explain problems. Their final papers often show a thorough survey of scientific literature on the topic, creative presentation of data, and thoughtful arguments to explain results. Achieving this final point requires targeted guidance and engagement on the part of both student and instructor.

What has mattered most in this module is the learning process itself. The actual topic of research has been secondary to the process, although a project with a connection to the local environment has been meaningful for the students. Going through each step of the scientific discovery process, including its uncertainty and frustration, gives students a realistic view of thinking and working like a scientist. Working collaboratively with peers in laboratory procedures—in making decisions about data analysis and presentation—and in actively discussing arguments stresses the critical role of collaboration in scientific discovery and inquiry. Previous preparation and experience with scientific investigation and inquiry in the first course ensured more success for students (*9*).

The open-ended nature of investigating outcrops allows the research module to evolve from year to year, exploring new approaches and questions informed by past student projects. Each new class thus remains enthusiastic about being part of a larger research initiative. Expanding the framework of this module to incorporate new topics or interdisciplinary connections and teaching students how to effectively use shared data are future goals.

About the author

Nitya Jacob, Ph.D., is associate professor of Biology at Oxford College, an undergraduate division of Emory University, located in Oxford, Georgia, at the historic original campus of the university. At Oxford College, she teaches courses in cell biology, genetics, and molecular biology and a nonmajors course focusing on science and communication. She is the current director of the Oxford College component of the Summer Undergraduate Research at Emory (SURE) program. Dr. Jacob is a councilor in the Biology Division of the Council on Undergraduate Research (CUR) and was recently selected as a participant in the inaugural Assessment Residency of the American Society for Microbiology (ASM) and National Science Foundation (NSF) Biology Scholars Program.

Thinking time! Students work collaboratively in research teams to actively discuss data analysis and synthesis.

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