Tips and Tools

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Characterizing *Staphylococcus aureus* from Healthy Individuals: an Authentic Research Experience for Undergraduates

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INTRODUCTION

Instead of providing undergraduate research experiences through independent faculty-student collaborations, as is typical at small primarily undergraduate institutions, in the Concordia University Science Department research is run as a course. For many years department research offerings were limited to a single course which provided on-campus research opportunities for up to 8 students per year and was taught by the same faculty member each semester. The opportunities available through this program were sufficient for our department until the number of our majors doubled, increasing from 50 to 100 from one fall to the next while our full-time faculty remained the same at 6. To accommodate the needs of this larger student population our department needed to create additional on-campus research opportunities that would be sustainable, ongoing, and scalable.

Several large-scale research experiences for undergraduates exist, including Science Education Alliance-Phage Hunters Advancing Genomics and Evolutionary Science program (SEA-PHAGES), TinyEarth, and the Small World Initiative (1–5). We opted to build our research program around *Staphylococcus aureus* as it provides a unique opportunity in that it is an opportunistic pathogen (it can live in or on one's body without causing disease), but it can also be pathogenic if given the right circumstances (6). Because 30 to 40% of individuals carry *S. aureus* (7), we have a high likelihood of collecting a positive isolate. This aspect of the study ensures that our pool of *S. aureus* isolates needing characterization will continuously grow. In addition, because it is also a well-known pathogen with the ability to become antibiotic-resistant and to make a variety of virulence factors, many avenues for exploration are provided (8–10). Furthermore, most studies looking at pathogenicity use strains that have been isolated from diseased patients. Our study is unique in that it allows for the study of the same organism with the same potential to cause disease, but isolated from healthy individuals.

These factors have enabled us to conduct research with at least 10 students each semester since the study's inception 5 years ago (this is over and above the original 8 per year). During that time, 92 students ranging from sophomores to seniors have completed 146 semesters of research with us, increasing the number of research opportunities for students on campus.

PROCEDURE

Part of the development of a new research program involved considering ideas that would allow for a long-term, ongoing project with multiple avenues for exploration. We also wanted to ensure it would provide students with key skills that would be useful in the job marketplace, that it would be relatively easy to implement and sustain with regard to necessary equipment (see Appendix 1) and ongoing funding, and that it would be relevant from a scientific inquiry vantage point. Since aseptic technique and molecular biology research skills are usually at the forefront of most entry-level biology jobs, a research program that emphasized that was preferred. Student learning outcomes were then developed to promote the acquisition of these skills (see Appendix 2). Moreover, gaining those key skills does not rely on expensive, large equipment. Instead, it relies more heavily on consumables (*i.e.*, plates, media, reagents) and equipment that were already available through our teaching labs.

In the Staph Study, students collected nasal swabs and a short survey from consenting adult participants and determine whether *S. aureus* was present in the samples through analysis of the results of six culture tests (mannitol fermentation, DNase, coagulase, catalase, Gram stain, blood agar hemolysis). The isolated strains of *S. aureus* were then further tested for antibiotic resistance (*i.e.*, are they methicillin-resistant *S. aureus*, or MRSA?) and the presence of several toxin genes known to be correlated with infection symptoms and severity. Eventually, the isolate results will be related to survey data collected with the original nasal swab.

Running research as a course creates the opportunity for lots of students to participate, but this means that the project and the mechanics of the course need to enable many students to

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participate simultaneously without eroding the novelty of the student's work or the quality of the instructor interactions. We accomplished this by dividing the research work into two parts, an initial experience for first-timers (newbies) and a more advanced experience for second-timers (repeats). In the newbie experience (see Appendix 3), the entire group of students moved through stages of learning about the study, *S. aureus*, human subjects research, lab safety, moving into testing lab strains of *S. epidermidis* and *S. aureus*, testing study samples of known profiles, and testing their assigned unknown samples. Each stage was a gateway in the sense that an individual student was not allowed to progress to the next stage until the previous was completed satisfactorily. For example, students started with a mixed nasal culture and first had to go through a series of isolation plates using mannitol salt agar, proving that they had isolated a single species before performing additional culture tests. To ensure student results were of sufficient quality and that we understood what they found, we implemented highly structured data collection expectations using shared Google docs, which we are willing to share with interested parties. This enabled us to keep up with student progress in real-time and to collect trustworthy results from each student, which were our two biggest research program hurdles. Students who were interested in research and motivated to work more independently continued in a subsequent semester to the optional repeat experience (see Appendix 4), gaining skills in Kirby-Bauer assays, toxin gene profiling by PCR, and interspecies inhibition assays to identify novel antimicrobials. Students developed a spectroscopy enhanced Kirby-Bauer assay, PCR protocols for several toxin genes, and protocols for finding the production of antimicrobials.

SAFETY ISSUES

Working with a potential pathogen required some additional steps and precautions for the research experience. Students performed initial online lab safety training modules on biosafety level 2 (BSL2) labs and bloodborne pathogens through SafetySkills (www.safetyskills.com). We then trained them to follow all ASM Biosafety Guidelines for working with BSL2 organisms. Students were then given a lab strain of *Staphylococcus epidermidis* to practice plate streaking, and a week later they were individually tested on that technique. Students that did not pass were asked to practice some more and retest until they passed before they could move on. We then increased the stakes so that they were slowly handling more and more potentially pathogenic strains, first a lab strain of *S. aureus* followed by some characterized study isolates and unknown study isolates. While they were handling samples taken from other individuals, they were doing so in a dedicated BSL2 lab.

CONCLUSION

The department has long held the belief that research is a vital part of the training process for scientists. With the addition of the Staph study, the department was able to make a single semester of research a requirement within our Bachelor of Science degrees. Running research as a course provides workload for faculty and accounts for budgetary funds and lab fees to be used to cover most costs. The simplicity of the equipment and techniques have enabled us to streamline the experience into one in which students travel as a cohort through technique acquisition, confidence enhancement, and testing in a modular way, limiting redundant instruction in favor of one-on-one interactions. These combine to allow 1 to 2 faculty to oversee a larger number of students at one time.

SUPPLEMENTAL MATERIAL

Supplemental material is available online only.

SUPPLEMENTAL FILE 1, PDF file, 0.04 MB.

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