Culturing Life from Air: Using a Surface Air System to Introduce Discovery-Based Research in Aerobiology into the Undergraduate Biology Curriculum

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INTRODUCTION

Although the field of aerobiology predates Louis Pasteur’s classic late 19th century experiments illustrating the existence of airborne microorganisms, the atmosphere has recently emerged as a frontier of exploration in the field of microbiology (5). Recent research demonstrates that airborne microorganisms can remain metabolically active, can influence atmospheric chemistry and meteorological patterns (4), and are highly diverse, making the atmosphere worthy of bioprospecting for microorganisms with potentially novel functions (e.g., production of novel enzymes and antibiotics, see Appendix 1) (6). Continued aerobiology research will yield discoveries in the basic science arena and potentially pave avenues to biotechnological innovation that improves the life of humans.

However, airborne microbes are not widely studied in laboratory courses. One reason may be lack of proper air sampling equipment. Airborne microbes can be cultivated on settle plates, but this method is not quantitative and leaves many variables to adversely impact “sampling”; with the right equipment, however, airborne microbes can be collected from defined volumes of air within a framework of student-generated hypotheses.

We describe how a surface air system (SAS) can make aerobiological research accessible to undergraduates. The SAS facilitates incorporating student-driven, discovery-based research into the curriculum while simultaneously teaching core biological concepts and laboratory skills (Table 1). Using a SAS, undergraduates at Idaho State University (ISU) generated data that were presented at a national meeting and made a genuine contribution to the field (Appendix 1).

PROCEDURE

Surface air system description, operation, and practicality

The SAS SUPER 180 is rechargeable, battery-powered, and weighs only 1.7 kg (Fig. 1) (3). Air is sampled onto a 90-mm standard petri dish containing agar media through a stainless steel, autoclavable aspirating head at a fixed speed (180 L/min). On the aspiration head, 219 holes are arranged to distribute particles evenly across the medium; the high flow rate collects particles as small as one micron with 100% efficiency (3). The instrument records run data (e.g., volume sampled, date, time). The start time can be delayed if the user wants to leave the sampling area before collection begins (3). Any agar growth medium can be used, ranging from plate count agar (PCA) and potato dextrose agar (PDA), to enumerate total viable bacteria and fungi, to highly selective media (e.g., MacConkey’s Agar), to detect specific taxa.

Operation. 1. On the instrument panel, select the volume of air to be collected (≤ 1,999 L) and program the delayed start (if required). 2. Using aseptic technique, unscrew the top of the aspiration head, insert a petri plate into the clips, and quickly replace the top. 3. Orient the instrument in the desired location and press “start” (reverse can be done with delayed start). 4. After the instrument sounds, indicating sampling completion, remove the plate from the instrument, quickly cover the plate with lid, and label and store for transport to the laboratory. 5. Clean the aspiration head using ethanol and repeat the procedure for the next plate.

Students found this instrument very easy to use, and its rugged construction left us with few reservations about having students take this instrument into the field. After purchasing the SAS SUPER 180 ($4,950), which is nearly maintenance-free, the only consumables needed are petri plates and growth media, which are generally purchased with student laboratory fees. In the long term, this makes the instrument a cost-effective way to implement undergraduate-driven research in the biology curriculum. A less expensive instrument that may suit project needs is the BA-SIC AIR (NeuTec Group, Inc., Farmingdale, NY), for $2,426.
In fall 2013, ISU Biology I students based their research on an exploratory question: What kind of growth medium, defined, complex, or selective, would culture the greatest morphological diversity of bacteria from air? Students observed an abundance of Actinomycete-like colonies. After becoming interested in this taxon’s ability to produce antibiotics, they isolated Actinomycete-like colonies, confirmed their identity via 16S rDNA sequencing and performed inhibition assays to determine which isolates produced antimicrobial compounds. The majority of their isolates produced antimicrobial compounds. This result was presented at the 114th General Meeting of the American Society for Microbiology with the hypothesis that the lower atmosphere is an untapped reservoir of antimicrobial compound-producing bacteria (Appendix 1).

Numerous student-generated questions can be addressed using a SAS, while students also learn basic laboratory skills and Core Concepts for Biological Literacy (Table 1) (1). Outside of the laboratory/field experience, the latter was reinforced through selected reading and writing assignments based on the primary scientific literature, whenever possible, and textbooks when necessary (Appendix 2). These assignments provided fundamental understanding of aerobiology, including the diversity of aerobic microorganisms and their role in the environment.
knowledge that emphasized one or more Core Concepts and asked students to immediately apply this knowledge to formulate hypotheses. For example, writing assignment 3 (Appendix 2) emphasized the concept of “structure and function”; it required students to research how antibiotics inhibit cellular activities and made them apply their new knowledge to make hypotheses regarding what microbes they would cultivate on different types of selective media.

**Safety considerations**

Instructors and students should be aware that pathogens could be cultured from air. Manipulating microbes on agar plates poses a risk of creating aerosols. Students and instructors should follow the Guidelines for Biosafety in Teaching Laboratories for working with BSL2 organisms (2).

**CONCLUSION**

Biology I students successfully utilized a SAS to collect novel antibiotic-producing Actinomycetes from outdoor air. This discovery contributed to the field of aerobiology and students simultaneously learned core biological concepts and laboratory skills. Student enthusiasm for this project was high enough that two students continued working on this project in the semester following Biology I. We conclude that a SAS is a cost-effective research and educational tool that will enable us to conduct research with undergraduates in many semesters to come.

**SUPPLEMENTAL MATERIALS**

Appendix 1: Student poster presentation (114th General Meeting of the American Society for Microbiology, Boston, MA, May 17–20, 2014)  
Appendix 2: Reading/writing assignments to complement laboratory/field experience and reinforce the Core Concepts for Biological Literacy

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