Small Organisms with Big Consequences: Understanding the Microbial World Around Us

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Abstract

Creating a hands-on lab that conveys important information while simultaneously allowing for student autonomy can be difficult. This is particularly true for the field of microbiology, in which labs often rely on "recipe-style" instructions and materials that can be difficult to scale up for larger class sizes. For these reasons, microbiology concepts are often left out of introductory biology labs, the ramifications of which have been made apparent during the recent COVID-19 virus pandemic. Fundamental microbiology concepts, e.g., the prevention of communicable diseases, are important to teach in introductory biology classrooms – often a student's only exposure to biology in their academic careers – in order to create a healthier community as a whole. Therefore, this general biology lab introduces an active-learning microbiology lab that teaches students about the microbial world. Students are first introduced to the three major types of symbioses and apply these concepts to microbial organisms on a symbiotic continuum. Next, the students are given examples of mutualistic bacteria, i.e., the human microbiome, through a mini lecture prepared by the instructor. The students are then introduced to examples of parasitic/pathogenic microbes that can interfere with human health and cause relatable diseases (e.g., diarrhea, STDs, and athlete's foot). Students then apply this information through a short matching game before learning common practices used to prevent the spread of these pathogens, including an active learning exercise and video on how to wash their hands like healthcare professionals. Finally, students are asked to generate their own questions about microbes before working through a handout that guides the students in using the scientific method to address their questions. This exercise thus provides students with the autonomy to ask their own questions about microbes, design their own experiments, prepare growth media their own way, and present their findings in a way that is both scalable for large class sizes and reduces the burden of lab prep common for microbiology labs.

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Supporting Materials: Supporting Files S1. Understanding the Microbial World – Pedagogical Merit; S2. Understanding the Microbial World – Microbes Matching Game; and S3. Understanding the Microbial World – Handout.

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Learning Goals

Students will:

- Be able to identify the three major types of symbioses.
- Understand the sliding scale of the symbiotic continuum with regards to microorganisms.
- Practice techniques used to prevent the spread of common pathogens.
- Apply the scientific method and participate in the peer review process.

Learning Objectives

Students will be able to:

- Make educated decisions about their eating habits as they pertain to gut microbiome health.
- Provide examples of human pathogens and associated disease (e.g., dermatophytes and athlete's foot).
- Practice disease prevention (e.g., washing their hands like healthcare professionals).
- Apply the scientific method to everyday questions.

INTRODUCTION

The recent outbreak of COVID-19 has taught us that a general understanding of disease transmission and vaccines is vitally important for everyone, not just health professionals. The general public's lack of understanding about disease transmission (1) was compounded with active misinformation campaigns on the Internet (2-4), further highlighting the importance of microbiology education and critical thinking skills as an important tool for improving public health and wellness (5). Introductory biology classes, specifically those for non-majors for whom the course is likely to be their first and last exposure to the topic of biology at the college level, present an excellent opportunity to educate high school and college-level students about topics that will have a lasting impact on their lives, regardless of the career path they choose. While most intro bio courses cover topics like global climate change, identifying reputable sources, and evolution, public health and the basic information about disease transmission vital for quality of life are topics not always present in the curriculum. This is partly due to the necessity for complex tools like microscopes, lab material costs, and lab prep time that often accompany the exploration of microbial life, particularly in high schools where funding for science education is lower than that of universities in the US. Therefore, to make microbiology labs more accessible, this lab exercise was created with three goals in mind: 1) Provide students from all disciplines with a fundamental understanding of microbes that impact human health, both in positive and negative ways, 2) do so in a way that facilitates active learning, and 3) do so in a way that is cost effective and scalable for all class sizes, regardless of access to scientific tools.

To accomplish these goals, the lab is designed to have two modules divided across two in-class days. The components of these modules include a brief introductory lecture, to be provided by the instructor, followed by a self-guided active learning exercise that allows the students to formulate their own questions and apply the scientific method on day 1, and a literature review followed by a student-driven presentation of their findings on day 2. In the lecture portion, students are introduced to the basic concept of symbioses, followed by the more advanced topic of the symbiotic continuum, demonstrating that microorganisms exist on a sliding symbiotic spectrum and are not always fixed to one of the three general symbiotic categories (mutualism, commensalism, or parasitism). Examples of mutualistic microbes, e.g., the human microbiome, are then covered to highlight their vital role in human health, overall dispelling the notion that all bacteria are "bad." The lecture expands on this learning objective by covering the many ways in which humans have harnessed the power of some of these microbes to benefit humanity (e.g., the use of fungi for food preservation or bacteria for oil spill cleanup). Once the students understand the benefits of some bacteria to human health, the lesson then transitions into commonly known parasitic/pathogenic microbes that cause a myriad of relatable diseases ranging from the common cold, to food poisoning, to athlete's foot. This portion of the lecture is designed to allow teachers the ability to select which types of diseases to cover depending on the age of the students. For example, while gonorrhea may be a more relatable and important bacterial disease for college-age students, food poisoning may be a better example to cover in early high school classrooms. Students are then "tested" on their pre-existing knowledge of common pathogens through a group-oriented active learning exercise. Designed as a matching card game, the exercise consists of names and pictures of microbes that must be matched with their corresponding diseases, with the goal of helping students build connections between the course material and things they are familiar with in their everyday lives. The class will then collectively go over the correct pairings before the lecturer provides more details on each pathogen. Finally, the students are introduced to hygienic practices that help stem the spread of pathogenic microbes, primarily hand washing. While everyone has "washed their hands" before, almost everyone does so incorrectly, at least according to healthcare professionals. Students are therefore introduced to the methods healthcare professional are trained to use when washing their hands in a hospital environment. To demonstrate how proper handwashing improves hygiene, students will participate in a second active learning exercise where they test their hand washing skills wearing nitrile gloves and "washing" them with acrylic paint. Students should first attempt the exercise with their eyes closed before repeating the exercise after learning how health professionals wash their hands. Once students have been introduced to these microbes and best practices for disease prevention, they then begin the second part of the module by writing down a question they have about the microbial world around them. This portion of the class allows for a great deal of student autonomy; however, depending on the overarching theme the instructor wishes to portray, limitations can be applied to narrow the scope of questions while still allowing students to choose their questions. For example, if the focus of the lab is on human health and disease transmission, example questions could be limited to which hand cleaning procedures are most effective, how much bacteria is spread through coughing, or how much bacteria is on commonly touch objects like cellphones or doorknobs? While this limits the types of questions that students may ask, they are still free to come up with their own projects. A provided handout then walks the students through how to form a hypothesis and design a proper scientific experiment to answer their question using the scientific method.

One of the ways this lab incorporates higher forms of learning as outlined by Bloom's Taxonomy, as well as reduces prep time for the instructor, is to provide the students with the autonomy to not only design their own experiment, but to create their own growth media as well. This broadens the field of possible questions the students can explore, including questions that might stem from their own life experiences or that pertain to their current career interests in the case of non-majors (See Supporting File S1. Understanding the Microbial World – Pedagogical Merit for more information on the pedagogical merits of this lab). For example, perhaps a future nutritionist is interested in how bacteria grow on agar with different amounts of sugar, or a public health student is interested in whether ethanol or soap is better for washing hands. This lab allows both students to ask their own unique questions and provides them with the tools to adjust their experiments accordingly. And because the students are creating their own growth media, there is less need for media preparation prior to the start of lab.

After gathering results on day 2, students are instructed to design and conduct a gallery-style presentation using the

tools available in an active learning setting. This typically includes the use of whiteboard space to draw diagrams of their experimental workflow with bulleted information outlining their hypothesis, results, and conclusions. In the event that whiteboards are not available, posterboards and markers are commonly used substitutes. The students should use the information recorded on their handout to aid in the creation of their presentation. Students are then introduced to the concept of peer review, as each student is required to provide critical thinking feedback for their peers in written form. By organizing the students' projects in this way, each student is able to see the kinds of questions and answers that other students have come up with. It also provides student-led peer evaluation for grading, as well as provides an easy way for instructors to evaluate student performance.

Intended Audience

This lab was designed as a university introductory lab for either first year biology majors or non-biology majors across disciplines; however, the course can easily be adapted for use in high school classrooms as well. One of the major design benefits is the ability to scale the lab up for larger class sizes without increasing material preparation time for the class. The lab was tested on a student population of 300+ individuals in a series of introductory biology for non-major courses with about 24 students per class.

Required Learning Time

The class is designed for two separate, two-hour class periods. This is primarily due to the incubation time necessary for the bacteria and fungi, requiring a follow-up lab for results. At room temperature, this incubation period can take from three to seven days. It is therefore recommended that the lab be conducted across two lab periods about one week apart.

Prerequisite Student Knowledge

A fundamental understanding of cells is helpful for understanding how microscopic organisms survive and operate.

Prerequisite Teacher Knowledge

The instructor should familiarize themselves with symbioses and the symbiotic continuum, the microbiome, various relatable bacterial and fungal pathogens (and viruses if the instructor so chooses to include them in the lecture, although the exercise portion of this lab is unable to incorporate tests for viruses), general microbiology media preparation protocols to aid students, different forms of peer-reviewed literature, and active learning.

SCIENTIFIC TEACHING THEMES

Active Learning

This lab is set up to engage students using the top five tiers of Bloom's Taxonomy; Understanding, Applying, Analyzing, Evaluating, and Creating. Students are given the autonomy to decide what research questions to address and how to design an experiment to formulate and test their hypothesis using the scientific method. Students then create a presentation to share their findings with fellow students in a gallery-style walkthrough and provide critical thinking feedback for their peers' work. Furthermore, students with similar questions are encouraged to work together and pool their resources for larger sample sizes, encouraging but not mandating group learning. This provides a hands-on active learning approach suitable for both extroverted and introverted individuals to tests the questions they find most interesting while eliminating social phobias that may interfere with their overall learning (6). See Supporting File S1. Understanding the Microbial World – Pedagogical Merit for more information on the pedagogical merits of this lab.

Assessment

Students are provided with a handout that guides them through the process of formulating a hypothesis, designing an experiment, and presenting their work. By filling out the handout as they go, students can self-check their progress and the progress of their peers. This handout also acts as a tool for instructors to evaluate the student on their work. At the end of the handout, students are instructed to create a gallery-style presentation and to view at least three other projects to provide critical feedback about their work. This allows instructors to monitor the results of each student's experiments and for the students to provide peer-evaluations for other student's work.

Inclusive Teaching

The design of this lab is inclusive for all students across personality types. It actively encourages group learning, but also provides a path for independent students to work on their projects on their own if they wish. Furthermore, because the students are designing their own questions, choosing their own testing locations, and making their own media, the class is inclusive for all students across different disciplines (e.g., a public health professional can swab different surfaces of the classroom, while an athletic nutrition major may test agar medias with various concentrations of sugar). This allows students to apply what they are learning about biology and the scientific method in a way that applies to their future careers and goals, making the lecture material much more likely to stick with them. A group-oriented option included in the handout designed for the pooling data does however introduce the potential for student exclusion. See the "Common Issues" section of the "Teaching Discussion" for tips on how to modify the lab to reduce this phenomenon.

LESSON PLAN

Before Class

Have students watch the video, "How Bacteria Rule Over Your Body" or one of your choosing introducing the topic of the human microbiome before coming to class.

The Lecture

Present a mini-lecture, about 30 minutes, covering the following material:

- Begin the lecture with an introduction to the three major types of symbioses: mutualism, commensalism, and parasitism.
- Introduce the concept of microbes and discuss how they interact with humans across a spectrum of symbiosis that can change over space and time (the symbiotic continuum). Define the term "microbe"

as a "microscopic organism," although viruses (not technically living and therefore not technically considered organisms) are included as well. The meeting review *Symbiosis in the microbial world: From ecology to genome evolution* provides excellent background information about microbes and the symbiotic continuum (7).

- It may be a good idea to watch the first few minutes of the assigned video above in class to refresh the students' memory and to provide basic information to those who inevitably did not do the assignment.
- Introduce the six major types of microbes:
    - Bacteria and Archaea (Prokaryotes)
    - Yeast, Algae, and Protists (Eukaryotes)
    - Viruses
- Introduce the microbiome. Inform the students that they are in fact made up of more bacterial cells than their own eukaryotic cells at a factor of roughly 10:1 (although eukaryotic cells are much bigger than bacteria, and therefore comprise the majority of one's mass).
- Introduce the seven ways in which microbes (particularly fungi and bacteria) aid the human body in various systems:
    1. Protection against pathogens (8)
    2. Aid in synthesis of certain vitamins (9)
    3. Development of immune system (10)
    4. Promotion of intestinal angiogenesis (11)
    5. Promotion of fat storage - useful evolutionarily, albeit undesirable by some (12)
    6. Aid in fermentation and digestion of dietary fiber (13)
    7. Communication and modulation of the central nervous system (14)
- Discuss the history of humanity's application of fungi and bacteria:
    - Fungi – Fermentation (and ultimately purification) of drinks, bread making, preservation of foods (e.g., cheeses and meats), and synthesis of antibiotics
    - Bacteria – Food and drink culturing (e.g., lactic acid production in yogurt/sour beers), transgenic expression of compounds for mass production (insulin), and bioremediation of oil spills
- Watch the video about E. Coli deaths or one of your choosing that demonstrates the risk of communicable diseases (e.g., measles, whooping cough, and COVID-19):
- Introduce the concept of pathogens as "a parasitic microbe capable of causing disease." Discuss how pathogens seek to take advantage of the human body's microbiome, an ideal set of resources for microbial growth.
- Introduce the concept of disease and explain that when pathogens are successful at colonizing the human body, they present in a particular "signature." The "signature" could be a set of ailments caused either directly to the human body or indirectly through competition with the microbiome or body defense responses (e.g., fever).

In-Class Activities

Lead the students through the "How well do you know your pathogens?" active learning exercise (Sample included in Supporting File S2. Understanding the Microbial World – Microbes Matching Game). This exercise is a simple matching card game where the pictures and descriptions of a microbe are on one card and an example and description of the corresponding disease are shown on another. The students should work in small groups, either based on proximity to one another or by instructor assignment when appropriate, to discuss what they know about the listed diseases. The lists are easily modifiable to include the microbes you would like; however, you should try to incorporate a mixture of more recognizable microbes/disease (e.g., gonorrhea, athlete's foot) with less common examples (e.g., whooping cough, aspergillosis).

After 10-15 minutes, reconvene the class and talk about each microbe and its correct corresponding disease. Depending on the learning objectives for you class, you may spend more or less time on this section, going into more or less detail about each microbe. For a general education class, the goal is simply to help the students recognize their preexisting levels of understanding of microbes while teaching them about other common diseases they may not know about.

Talk about preventing the spread of disease through hygienic practices. Discuss with the students that the number one entry point for pathogens is through the mucus membranes of the face (i.e., eyes, nose, and mouth). Non-airborne pathogens reach these orifices through contact with the hands (i.e., rubbing eyes, picking nose, touching mouth). Students also tend to become more engaged if you inform them that there are 10 times as many microbes on their phones than on the average toilet seat (this may also help the students start to generate ideas for their lab experiment).

Introduce the concept that hands act as active transport for pathogens from the environment into our bodies, and present the students with the peer-reviewed study showing that participants touched their faces on average 15.7 times/hour).

Introduce students to the idea that there is a right way to wash your hands, and that it reduces transmission of diseases so well that healthcare professionals are trained to do it in this way.

Lead the students through the "Handwashing Competition" active learning exercise. This simple exercise demonstrates how well students wash their hands. Each student should put on a pair of non-latex nitrile gloves. The instructor should then apply a dab of green acrylic paint to the palm of the gloved hand, just as one would do with soap. The students should then close their eyes and wash their hands as they would normally. When the student thinks they are finished, have them open their eyes and observe the areas they missed.

Following this exercise, watch the instructional video from the CDC, or one of your choosing, on how healthcare professionals wash their hands:

Optional: The "Handwashing Competition" can be repeated to see if what the students learned from the video has improved their hand washing performance.

List a variety of other practices that help prevent the spread of disease:

- Get vaccinated (especially if you are around infants or the elderly on a regular basis).
- Use antibiotics appropriately (e.g., finish full course and don't use for viral disease).
- Stay home when you are sick.
- Never eat food that has been left out at room temperature.
- Practice safe sex.
- Don't share personal items (e.g., toothbrushes, combs, straws).

Present the open-ended question: What do you know about the microbes that live around you? to the students and ask them to think about things that they find interesting or applicable to their majors (e.g., hygiene for health professionals, nutrient concentrations for nutritionists/athletes).

The Lab

Have the students work through the handout (Supporting File S3. Understanding the Microbial World – Handout):

This handout will guide the students through creating a hypothesis about microbes, identifying the variables in their hypothesis, designing an experimental test, preparing media for the growth of fungal and bacterial colonies, collecting samples from the environment, performing a mini literature review, evaluating their results, identifying and differentiating bacterial and fungal colonies, presenting their data, and performing a peer review.

Lab Day 1 Overview

Part 1 and 2 of the lab will walk the students through designing a hypothesis. Nothing is required except for the handout for this portion.

Part 3 of the lab will involve the students creating the growth media for their research project. For many, this will be the standard PDA media (instructions on which are located on the premix container). For those who choose the media type as their independent variable, you will need to assist and monitor them as they modify the recipe included in the handout. This may include adjusting the level of sugars, proteins, or pH of the media. **This section contains a burn hazard when heating and pouring the media**. Please advise students accordingly.

Part 4 of the lab involves collecting samples. Some students may choose to swab their hands for bacterial samples, while others may choose location as their independent variable. The instructions allow students to leave the classroom for 30 minutes to swab several locations based on their experimental design; however, this is only necessary if the students elect to swab their environment and it not necessary if they are conducting an experiment addressing other health-related factors (e.g., how much bacteria is spread through coughing at various distances). High school classrooms may want to edit the language of the handout to keep students in the classroom. After the lab, make sure that students follow proper waste disposal of sampling material using appropriate biohazard waste containers (Note: while none of the procedures used in this lab require biosafety level 2 (BSL 2) protocols, it is a good idea to have them treat their experiment as though the samples contain pathogens). The students' samples will need to incubate until the next lab meeting (between 3-7 days). It is advised to do this at 25°C, or approximately room temperature. If incubators are used, do not exceed 30°C or you may kill the fungal colonies.

Lab Day 2 Overview

This portion of the lab is best performed in an active learning classroom environment.

Part 5 of the lab has the students perform a literature review for background information pertaining to their research question, teaching them about different types of science papers (e.g., research articles, rapid communications, review articles, and case studies). You should print and hand out good examples of each type of article pertaining to health and wellness, e.g., Baldwin et al., 2017; Garcia et al., 2021; Arena et al., 2013; Schleicher, Lowman, & Richards, 2020 (15-18). Due to the time sensitive nature of in-class exercises, it is advisable to only print out the abstract or introduction of each source for the students. It is recommended that students are only given excerpts from examples so that they can use more of their time to find articles for their project. Alternatively, the full articles may be useful for the students to scan over and identify differences in structure between article types (e.g., research article will have methods and results, while review articles will not); however, the students should still be instructed not to spend too much time reading the articles.

Part 6 of the lab has students analyze their results. The handout will walk the students through identification of colonies that have grown in their tubes and help them record their data.

Part 7 of the lab has students organize their project into a presentation for the class in a gallery style walkthrough.

Part 8 of the lab introduces the students to peer review and instructs them on how to learn from, and evaluate, their peers' presentations. Active learning classrooms or areas with lots of whiteboard space are recommended for this portion of the lab. Posters can also be used in smaller classes or where materials like whiteboards are less readily accessible. The instructor should collect the worksheets after this activity and grade them for accuracy and completion.

Materials Required for the Lab

- 2 mL Microcentrifuge tubes, 5 per student
- Sterile Swabs, 5 per student (cotton swabs can be ordered in bulk and autoclaved before use)
- Sterile water (autoclave distilled water, don't use tap water as it can contain other minerals and nutrients)
- Sterile gloves, 1 pair per student
- Potato Dextrose Agar (PDA) pre-mix
- Bacteriological agar powder
- Small 50 mL beakers, 1 per student
- Heating apparatus (hot plates recommended, but microwave can work)
- 1 mL plastic droppers/pipettes

Note: Students should be given the option to work with broths using any grocery store items; however, it may be useful to have stocks of things like V8 juice or protein powders, such as those used for workouts (e.g., whey protein).

TEACHING DISCUSSION

Student Reactions and Effectiveness of Materials

This lecture was tested in an introductory biology lab for non-majors (384 total students, 24 students per lab) at the University of Louisville as part of the Introductory Biology Lab Development Award. This project did not seek IRB approval, and therefore we do not have the data to share pertaining to student performance. The lab was, however, generally well received, with only a few issues experienced in some of the classes.

Common Issues

The first issue some classes experienced was with their growth media not setting (i.e., remaining a liquid in the test tubes). It is important if allowing students to make their own media to make sure they are adding agar at a 2% w/v ratio (i.e., 2 g of agar per 100 mL of liquid). The turbidity of the solution can also impact the setting process. It is recommended to advise students to use clear liquids as alternatives to dense or turbid ones (e.g., use chicken broth for proteins instead of muscle milk). Reasonable sugar concentrations (between 0-30% w/v) should not affect the setting of the agar. If the students are still having trouble with their media setting, try using 3% agar. You can continue to increase the agar concentration stepwise until the media sets properly, but it is recommended to try to stay as close to 2% as possible to make it easier for the microbes to colonize.

The second issue some classes experienced was a lack of bacterial/fungal growth. It is important for every student to make a "Control" tube containing the Potato Dextrose Agar (PDA) mix, especially those making their own custom media. Fungi and bacteria should readily grow on PDA, allowing students to judge if the lack of growth was due to their media preps or due to other conditions. Another important factor for bacterial or fungal growth is temperature. While many bacteria like hotter temperatures (e.g., 37°C), fungi, particularly environmental fungi found on many surfaces, prefer a temperature closer to room temperature and die if heated over 30°C. It is therefore important to make sure you are incubating at 30°C or cooler if using incubators, or simply leaving the tubes at room temperature. While bacteria prefer warmer conditions, they too will grow at cooler temperatures, albeit at a slower rate (this fact also presents a good learning opportunity about how foods go bad in the fridge). Leaving tubes at room temperature is also another good tactic for scaling the lab up to larger class sizes, but may require a few more days of incubation.

A third potential issue that instructors may encounter by allowing students to group together based on similar experimental questions, is the possibility for social isolation of students. While some students my prefer to work alone, especially more introverted individuals, others may be intentionally excluded from participating in a project with similar goals by cliques or groups of friends due to their social standing, race, religion, gender, disabilities, or sexual orientation. While our test runs were unable to test for this without IRB approval, this is presumably more of an issue in high school classrooms where students are more familiar with one another than in college classrooms, especially if students are in their first year. Instructors can mitigate the potential for exclusion of individuals by assigning groups based on the experimental questions that are submitted beforehand by students.

Improvements/Customization for the Lab

This lab was designed specifically to tackle the issue of scalability for microbiology labs at an introductory biology course level; however, the lab is fully suitable for smaller class sizes as well. A small group also allows for some modifications to factors that can make the lab easier and or more effective. One of these factors is media size. The small 2 mL agar tube slants, while effective at growing fungi and bacteria, can make it difficult to distinguish between individual colonies. With a smaller group, agar plates may be a better alternative for media prep. Agar plates come in a variety of sizes that can make it much easier to distinguish between individual colonies. Using larger plates allows for the addition of identification or colony count variables for the students' results data.

This lab also generates potential for collaboration between students/groups to achieve large sample set sizes. A mini-lecture about the importance of experimental replication and statistical power can easily be incorporated for lectures that seek to be group-oriented.

SUPPORTING MATERIALS

- S1. Understanding the Microbial World – Pedagogical Merit. An overview of goals and concepts.
- S2. Understanding the Microbial World – Microbes Matching Game. Example game pieces to cut out and laminate.
- S3. Understanding the Microbial World – Handout. A self-guided walkthrough of the lab for the students.

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Table 1. Timeline for the lab.

Activity	Description	Estimated Time	Notes
Preparation for Class			
Preparations for growth media, the microbe matching game, the handwashing competition, and the handout	1. Set out the materials for making the agar tube slants, as well as the sampling supplies. 2. You may need to autoclave water and swabs depending on your materials. 3. Print out the Microbes Matching Game, one per group, and The Handout, one per student. 4. Provide each student with one or two pairs of gloves and bring a small bottle of green acrylic paint.	About 45 minutes to prepare, depending on the speed of autoclave	• An example of the Microbes Matching Game is supplied as Supporting File S2. • The Handout is supplied as Supporting File S3.
Day 1			
Mini-lecture on microbes and starting the experiments	Interactive lecture with matching game, handwashing activity, and worksheet, followed by media prep and microbe sampling.	~2 hours	Lab supplies should be prepared in advance.
Day 2 (3-7 days later)			
Mini-lecture on peer-reviewed literature	Interactive lecture with peer-reviewed literature handouts, followed by an active learning gallery-style presentation of lab results.	~2 hours	Examples of different styles of peer-reviewed literature are listed in Part 5