PREFACE

Microbiology is one of those subjects that can interest everyone because microbes affect our lives in so many different ways, both positively and negatively. In my microbiology lecture, I begin the course with photos from 19th-century cemeteries that I took while on vacation in Maine. Similar to any cemetery from the 1800s, these photos show that many of the graves are of children who died of infectious disease. I use these photos to illustrate that we live in a very different world today, a world in which diagnostic methods and antimicrobial drugs have resulted in a dramatic decrease in childhood mortality, thanks to microbiology.

In my lab course, I tell my students that one does not have to be planning to be a microbiologist to appreciate that the methods of the microbiology lab have given us a greater understanding of the biological world, created useful products, and have saved countless lives. Students taking a microbiology lab will hopefully grow to understand and value the way in which discoveries have been made in this field of science and how they might make discoveries of their own in the future. My personal curiosity about the subject, and the fun of watching others develop their own interests in microbiology, while they gain proficiency with the field's methods, have made teaching these labs, and writing this manual, very enjoyable indeed.

My interest in microbiology dates back to the seventh grade when I first used a microscope in a biology class. I was already interested in biology, and the microscope opened up a whole new world of organisms which were fascinating, ubiquitous, and very significant in terms of their impact on us. As an undergraduate, I majored in microbiology and was also drawn to the sights and smells of the microbiology lab. There were so many media colors, so many kinds of microbes to observe, and everything was alive and growing. This was a type of biology in which there was no need to dissect dead, stiff, and colorless frogs and fetal pigs reeking of formaldehyde. Best of all, unlike the chemistry and physics labs, the microbiology labs actually worked.

After working with insect viruses in graduate school, I began teaching microbiology and ecology at a small college where I was able to be in the lab as the students worked. It was a real pleasure to watch students' confidence increase as they learned the basic techniques of the microbiology lab, and as their growing interest led them to ask questions that went beyond the immediate task at hand. In this environment, it was possible for me to directly explain the lab, observe student errors, provide verbal directions, and answer questions as they arose. This gave me ample practice in explaining the principles and concepts behind microbiology labs, and led me to anticipate certain common student errors in lab technique. These experiences are reflected in this manual, both in the introductory material and in the numerous notes to students in the protocols.

This changed when I moved on to work at a large university and began teaching through graduate teaching assistants, who were new to teaching, and in some cases, had not had a microbiology lab course as undergraduates. At this point, the lab manual became much more important as I was teaching primarily through the manual, but many of these manuals did not provide enough material to get the students interested in the labs or to thoroughly explain the labs, and more information was needed to reduce student errors. This motivated me to write a microbiology lab manual as a means of speaking directly to the students to increase their interest and understanding of the subject and to decrease the number of mistakes.

In writing this microbiology lab manual, I tried to keep the following things in mind:

- It can be challenging to get students to perform the essential task of reading lab manuals. If it's possible to avoid reading the manual, some students will act accordingly. So, I prepared a manual written in a more conversational style with a little humor and a few digressions to encourage students to read the manual and read it closely. Writing a manual is not exciting work, and I would often put in items that entered my mind by free association, in part, to make the work less tedious for me. However, I found that the students responded very positively to these mental wanderings, so I kept them in the manual to facilitate student interest.
- Most existing manuals are not as complete in terms of background information as they could be, so they are not as useful for lab courses taught by graduate TAs, who typically teach these courses at the larger research institutions. Manuals can leave out certain types of information if veteran microbiology instructors are in front of the classroom, because the instructors can fill in the gaps. However, graduate students are not experienced teachers and usually lack the depth of knowledge that is typical of more experienced microbiologists. This can be a problem when, for example, students raise questions that are not answered by the manual. As a lab course coordinator, I wanted to be sure that the students would get all of the information that they needed, regardless of who was at the front of the classroom.

- Students will also do and interpret things in unexpected ways. This is not surprising, given that most students in an introductory microbiology lab are completely new to the subject. In writing the manual, I tried to apply lessons learned from watching how students actually do the labs and from the observations relayed by TAs to anticipate how students will interpret and apply the information provided by a manual. Everyone is unhappy when a lab doesn't work, and so many steps in the protocols have additional notes designed to prevent some of the common errors that lead to disappointment. In contrast, success in lab leads to more interest, more enthusiasm, and a much better classroom atmosphere.

Microbiology: The Laboratory Experience is based on a manual that I prepared for teaching a multiple section introductory microbiology lab course at Penn State. We used that manual for several years, and it has been well-received by the students. Many students have commented that they like the extra quotes, analogies, and digressions, and that these additions made this one of the few manuals that they actually read. More importantly, the students have been able to follow the protocols and succeed in the lab, which has given them confidence and a very positive view of microbiology. Some students have even changed their majors to microbiology as a result of their experiences in this introductory lab course. We have also modified the protocols over the years, to address problems reported to me by our TAs. These changes have been intended to reduce confusion and common student errors. So, this manual has been well-tested and constantly improved, with the sole purpose being to promote the success of both the students and the TAs in the lab. Finally, it is my hope that lab instructors and students everywhere will find this manual to be a rich and useful resource for learning about microbiology.

FEATURES AND RESOURCES

The tendency in many microbiology lab manuals is to simply list steps for students to work through in lab protocols, resulting in their mechanical execution of lab work rather than promoting real learning. *Microbiology: The Laboratory Experience* avoids this common problem by using distinctive features, which promote genuine understanding of the microbiology behind each lab. These features include:

- **Extensive introductions** to each lab that explain concepts clearly and accessibly. This ensures that students—and inexperienced TAs—come to the lab session with the necessary background to not just go through the motions, but to actually learn. Most competing manuals simply ask students to follow a protocol and report results, but students who don't understand the composition of media, why a reagent produces a given reaction, or how a given method accomplishes a particular goal are just painting by numbers. These thorough introductions provide an antidote by explaining why procedures are performed in a particular way, providing context that enables students to meaningfully interpret the results of an activity. They also help students to understand the reasons behind the method, thereby preparing them to identify and correct errors that commonly lead to bad results.
- **Lab protocol sections which provide thorough explanations** for why certain procedures are performed in a particular way. This helps students to develop an understanding of the tools and techniques used in microbiology lab work. Because microbiology lab work can be overwhelming to undergraduates, the inclusion of **frequent hints and tips** that address common problems students encounter when doing each lab, also helps them to avoid potential mistakes.
- **Post-lab thought questions** that encourage students to consider how procedures and results can be applied beyond the classroom. These questions, which have been used by thousands of students at Penn State over the years, include:
  - "If you were a doctor, describe two cases or situations in which you might order a lab to perform an acid-fast stain."
  - "Assume that *Arthrobacter* cells do not secrete toxins into food, and consider what you've learned from lab results. Given that, would you be worried about the possibility of *Arthrobacter* multiplying in your body if your latest meal had been full of *Arthrobacter*? Why or why not?"
  - "Grape juice has a concentration of up to 25% sucrose. Assume, for the moment, that *E. coli*, *S. epidermidis*, and *S. cerevisiae* all fermented sucrose to produce ethanol and carbon dioxide. If all of these cell types produced the same fermentation products, would there be any reason to use *S. cerevisiae* to make wine instead of the other two species? Cite evidence from the lab to back up your answer."
  - "If you lost the labels on your *E. coli* and *P. vulgaris* stock culture tubes, how could you figure out which tube contained the *E. coli* cells?"
- **Dynamic visual content** which distills complex concepts and demonstrates correct lab procedures. In every lab, **impressive, up-to-date illustrations** created specifically for the manual, and others adapted from Norton's microbiology text-

books *Microbiology: An Evolving Science* and *Microbiology: The Human Experience,* present the visual content in an engaging manner. Showing students how to execute lab protocols through **photographs of lab procedures** is an important component of any microbiology lab manual; in this manual photographs were taken exclusively to match lab protocols in the manual exactly. Finally, it's important for students to see micrographs of the microorganisms they're studying, so the manual includes dozens of **meticulously researched micrographs.**

- An **engaging authorial voice**, using frequent anecdotes from popular culture and the history of science, draws students into the material. The extensive lab introductions are written in a conversational style, which motivates students to read before just jumping into the procedures. By including short histories that illustrate the process of scientific discovery and application, descriptions of the real world applications of lab methods, quotes from diverse sources such as The Beatles, Stephen Sondheim, Monty Python, and more, the author engages student interest, promotes careful reading of the manual, and most importantly facilitates actual learning.

Make no bones about it, adopting a new microbiology lab manual is a lot of work. But, to make the process easier, and perhaps even fun, Steve Keating has written a companion guide for instructors, ***Teaching Microbiology Lab, A Guide to Microbiology: The Laboratory Experience.*** This guide includes tips and tools for teaching successful, engaging courses, so it is also intended for lab coordinators who oversee large programs to distribute to their undergraduate and graduate TAs. The first half of the guide includes helpful suggestions for how to design a course and syllabus, create effective assignments and quizzes, interact with students or TAs, and much more. The second half provides a guide for teaching each individual lab with common student questions and mistakes noted, recommended sources for materials, instructions for media and culture preparation, suggestions for reducing costs and preparation time, answers to questions in the lab exercises, and ways to modify or expand on each lab.

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Sincerely,
Steve Keating

ABOUT THE AUTHOR

Steve Keating has been teaching and coordinating microbiology labs for 25 years. Over that time, he has acquired both a mastery of lab techniques and a catalog of information on the history and applications of microbiology lab methods. Steve earned his BS in Microbiology at the University of Maryland and his PhD in Entomology at Pennsylvania State University. He began his teaching career at St. Francis College (now St. Francis University), where he directly taught his students these microbiology laboratory techniques. For the past 15 years, Steve has taught microbiology at Pennsylvania State University, where he both lectures and coordinates the introductory lab courses in microbiology. Steve has twice won the Biochemistry and Molecular Biology Department's Althouse Outstanding Instructor Teaching Award.