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# Design and Revision of an Open-Educational Resource Microbiology Lab Manual Using Student Feedback

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Tips & Tools

# Design and Revision of an Open-Educational Resource Microbiology Lab Manual Using Student Feedback †

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## INTRODUCTION

In the past decade, the higher-education system has seen a movement toward the use of open educational resources (OERs) (1, 2). This has been driven by several factors, including the increasing cost of college textbooks and the desire for both access to a wider variety of materials and flexibility in content. An analysis of OER studies (3) indicated that they are as at least as effective as traditional textbooks and are often preferred by both faculty and students due to their reduced cost and the ability to customize as needed. In this paper, we describe the process by which we developed an OER microbiology laboratory manual based on student feedback. This manual has been published as an OER and is currently available at CUNY Academic Works (http://academicworks.cuny.edu/qb_oers/16/) under a Creative Commons Attribution-Noncommercial-Share Alike 4.0 License: (https://creativecommons.org/licenses).

Microbiology courses are an integral part of nursing education and other allied health professional training (4). Since healthcare workers, particularly nurses, will encounter infectious disease in their careers, they need to have a strong understanding of basic microbiological principles. At Queensborough Community College (QCC), Principles of Microbiology is a requirement for completion of the nursing program. Our microbiology course has a weekly three-hour laboratory component in which students perform hands-on experiments to reinforce key microbiology concepts. Through communication with our nursing faculty, we have learned that student performance in microbiology is one of the best predictors of success in nursing. Therefore it is important that microbiology instructors provide students with the tools they need to succeed in this gateway course.

The course previously employed a custom laboratory manual produced by a commercial publishing company. This manual had not been updated in many years and was in need of revision. There are several options for the choice of a laboratory manual, each with advantages and disadvantages (Table 1). Our decision to write an OER laboratory manual was driven primarily by the needs of our student population. QCC is an open admissions institution located in the urban environment of Queens, New York. QCC students are often the first in their family to attend college, and more than 50% of all students come from families with an income below $25,000 (http://www.qcc.cuny.edu/about/fast-facts.html). Community college attendees are often non-traditional students, and as such, they face additional roadblocks to successful learning. They may lack required background knowledge, they may be learning in a second language, and they often have multiple and diverse obligations extraneous to their studies. Therefore, they require additional resources tailored to their learning challenges to ensure their ability to succeed. Based on our student population, we decided to write our own microbiology laboratory manual and publish it as a no-cost OER. This paper describes the unique process by which we designed, implemented and assessed the lab manual using student feedback to guide stepwise revisions. It is our hope that our experiences will provide a roadmap for other instructors who also want to produce their own open access materials for classroom use.

## METHODS

### Approach to choosing content

The content of the lab manual is designed to reinforce concepts learned during lecture and is based on (1) the recommended curriculum guidelines for undergraduate microbiology education as described in 2012 by the curriculum task force of the American Society of Microbiology (https://www.asm.org/images/Education/FINAL_Curriculum_Guidelines_w_title_page.pdf) and (2) discussions with the QCC Nursing faculty.

Based on these guidelines and recommendations, we chose to focus on four broad topics: (1) use of the microscope/aseptic technique, (2) microbial identification (staining procedures/metabolic assays), (3) procedures for controlling microbial growth, and (4) clinical microbiology. We made significant changes to content, including restructuring the

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TABLE 1.
Comparison of different types of lab manuals.

| Type of manual | Advantages | Disadvantages |
|---|---|---|
| Existing published manual | • Readily available<br>• Field-tested<br>• Professionally produced figures | • Most costly option<br>• Extraneous exercises<br>• Not all lab materials may be available |
| Custom manual prepared by publisher (exercises pre-written by others) | • Easy to assemble<br>• Can choose only material desired<br>• Professionally produced figures available | • Moderate cost<br>• Difficult to revise individual exercises |
| Custom manual written by authors and published through a commercial publisher | • Can design and customize your own labs<br>• Professionally produced figures available | • Moderate cost |
| Custom manual; open educational resource | • Minimal to no cost<br>• Easy to revise and update | • Laborious<br>• Harder to incorporate professional figures |

midterm exam, adding a segment on microbial identification using the Biolog microplate system (www.biolog.com) and incorporating a comprehensive case study lab (not included in the manual but distributed during the last lab). In response to a specific request from the nursing faculty for an immunology component to the lab, we also included an exercise on ELISA (enzyme-linked immunosorbent assay) testing.

## Structure of the laboratory exercises

We formatted our exercises to include (1) learning objectives specific for the particular exercise, (2) key words that help students identify important concepts, (3) an introduction to the theory of the techniques/experiments, and the relevance to healthcare, (4) a description of experimental procedures (including diagrams), (5) a section to record results and draw conclusions, and (6) a series of review questions. In addition, simple line drawings were created to assist students in pathogen identification. We also included appendices containing information about exam formats and requirements for the lab report. Based on student feedback (see below) we included additional information about specific techniques needed for several labs (e.g., micropipetting) and additional exercises on topics that students find challenging (e.g., serial dilution).

Color is extremely important for the interpretation of many microbiological test results but adds a significant cost to printing. We supplemented our laboratory materials with an online component that includes images of slides, metabolic tests, and other materials for which color visualization is important. These resources are available on the Microbiology Review Site (Blackboard platform) and are accessible to all students registered for the course.

## Timeline

We took a stepwise approach to the design of the lab manual, both to make the transition to new content less abrupt and to allow us to consult with microbiology students and our fellow microbiology instructors during its development.

**Fall 2014:** The first stage of our revision process was to redesign the midterm lab practical. The new midterm is a multistep process that takes place over the course of several weeks, utilizes multiple laboratory techniques, and culminates in a formal lab report.

**Spring 2015:** We replaced several exercises following our new standardized format. In our earliest versions of the exercises we used figures from online resources; these were gradually replaced with figures drawn by an artist as well as photographs from our own laboratory. We also developed an end-of-semester lab as a series of case studies: in addition to serving as a review for the cumulative final exam, these allow us to assess how well students are able to synthesize information from various parts of the course.

**Summer 2015:** We identified two student readers to evaluate the content of the lab manual and the online resources from a student perspective. The two students (one who had just completed the course and one who was a health science major who had not yet taken it) met with us weekly to review and discuss one to two exercises each week. To keep the students on track, they were given a contract to read and sign explaining the work and deadlines for reading each exercise (Appendix 1). They were asked to fill out an evaluation form (Appendix 2) and provide comments and suggestions.

**Fall 2015:** We incorporated suggestions from the student readers, and the revised exercises were given to students as handouts over the course of the semester and were also made available to students on the course's Blackboard Microbiology Review Site. We provided some common quiz questions to all lab instructors to assess student learning using the new lab exercises (Fig. 1). A new laboratory exercise (Biolog) was introduced, and, at the

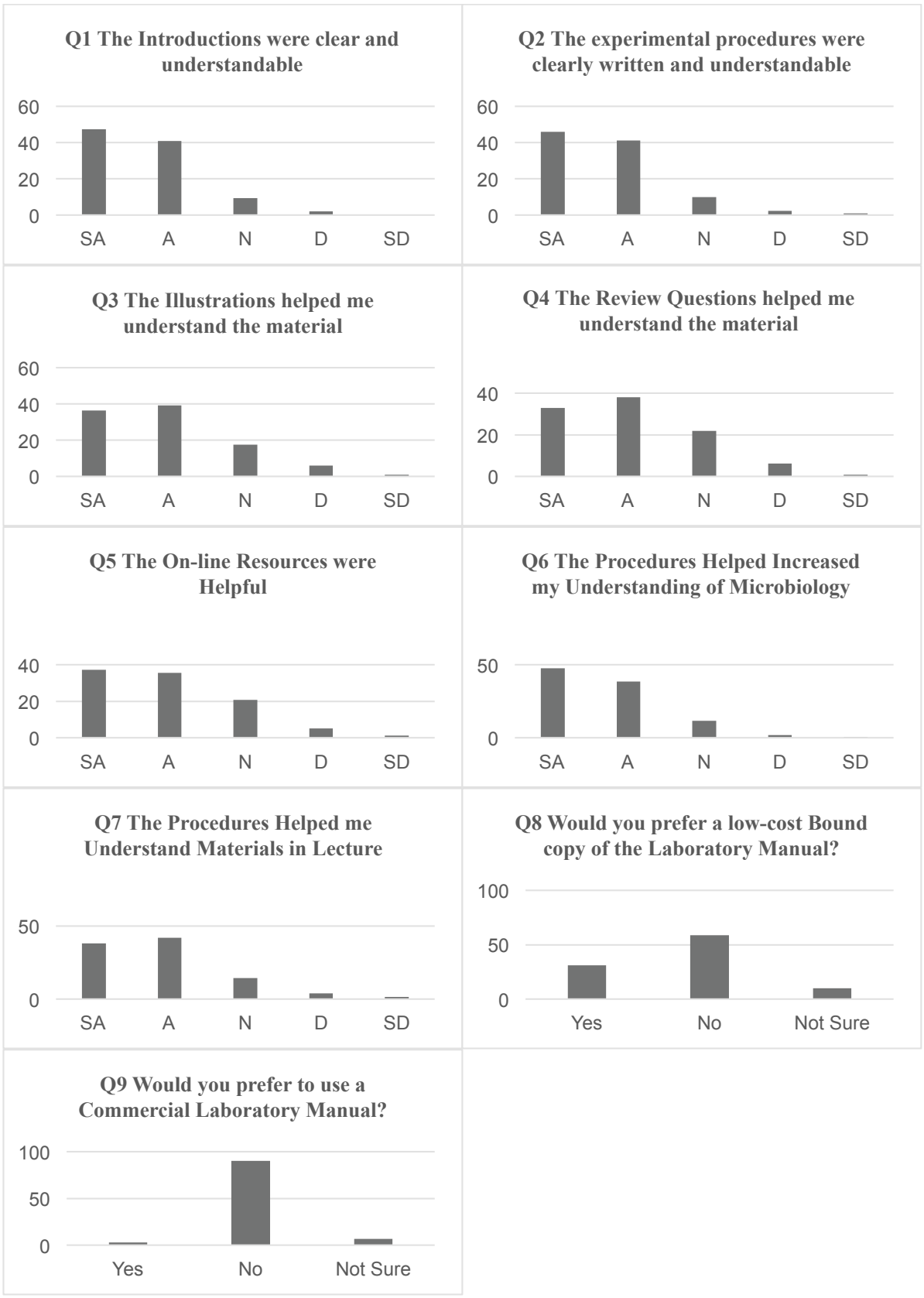



FIGURE 1. Results of student survey evaluating OER lab manual (combined data for fall 2015 and spring 2016 semesters). Bars represent percentages for each response. SA = strongly agree; A = agree; N = neutral; D = disagree; SD = strongly disagree; OER = open educational resource. N = 250–255 (exact numbers vary due to some questions being left blank).

end of the semester, surveys were given to all microbiology students to evaluate the lab manual (Appendix 3).

**Spring 2016 and fall 2016:** A second new laboratory exercise (ELISA) was incorporated in spring 2016. Additional figures and appendices were added, and final edits were completed in fall 2016. The lab manual was assembled into its final form and published as an OER.

### Student feedback and assessment

All assessments and survey tools were approved by QCC's IRB.

The lab manual in progress was assessed in the following ways:

1. Student reader evaluations: described above.
2. Student surveys: Surveys were distributed to all students enrolled in the course (fall 2015 and spring 2016) at the end of the last laboratory period. Students were informed that filling out the survey was voluntary. Surveys were completed anonymously and placed in a sealed box. They were collected and analyzed after the end of the semester.
3. Standardized assessment quiz questions: All faculty who were teaching microbiology labs in the fall 2015 and spring 2016 semesters were given standard quiz questions at the beginning of the semester and asked to incorporate them into their lab quizzes. The questions were chosen to assess students' understanding of several of the key concepts covered in the lab manual. Each topic included questions representing different levels of difficulty (Fig. 2 and Table 2) based on Bloom's revised taxonomy (5). The results of these quiz questions were reported to us by individual instructors at the end of the semester; data from both semesters were pooled to increase sample size.

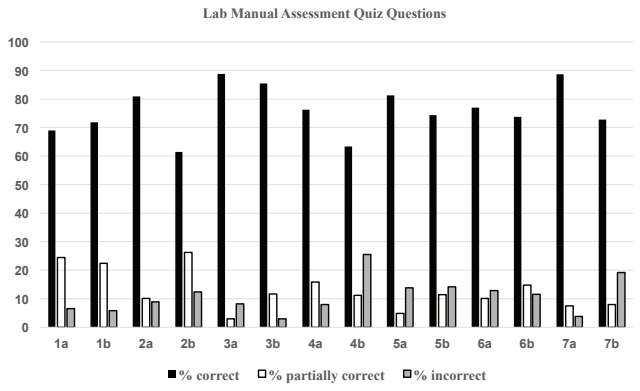



FIGURE 2. Results of assessment quiz questions for the fall 2015 and spring 2016 semesters. Values given as % of the total students answering each question. N = 206–258 (numbers vary due to students missing quizzes or withdrawing from the course). Quiz questions and Bloom's Taxonomy category are listed in Table 2.

## RESULTS

### Student reader evaluations

Overall, we received very positive feedback, as well as several suggestions for improvement covering both content and formatting issues. Student comments included "very detailed and organized," "objectives clearly stated," and "review questions really make you think!" In addition, student readers were satisfied with the amount of material, stating that it was neither too detailed nor incomplete, and they were also satisfied with the quality of the illustrations.

Several helpful suggestions for improvement were brought to our attention by student readers. Some of these suggestions referred to formatting (e.g., increasing line spacing to 1.5, using larger fonts for section headings, bolding key words in the text, etc.), while others were more content-oriented (e.g., provide online videos for procedures, requests for additional illustrations, etc.). Additional student reader comments are listed in Appendix 4.

### Student surveys

Students enrolled in microbiology in fall 2015 and spring 2016 were given a survey at the end of the semester to assess their satisfaction with the lab manual. Results are shown in Figure 1. The vast majority of students (88%) chose either "strongly agree" or "agree" when asked whether the introduction was clear and understandable; similar results were obtained for the experimental procedures (87%). A somewhat lower percentage of students (71%) thought the online resources were helpful (22% chose neutral for this question); 78% felt that the illustrations were helpful (18% chose "neutral" for this question). A total of 86% of students agreed that the lab increased their understanding of microbiology; 80% agreed that the laboratory procedures helped them understand content covered in lecture.

Students were also asked if they would prefer a low-cost (~$12) bound copy of the manual (instead of printing the exercises themselves): 31% responded "yes" and 61% responded "no" to this question. Students overwhelmingly indicated that they prefer the custom lab manual (90%) to a commercially available book (3%).

Examples of student comments are summarized in Appendix 5.

### Lab quiz question assessment

Results for content assessment based on the seven standard quiz questions are found in Figure 2.

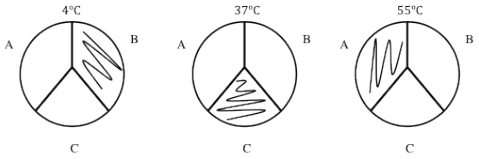
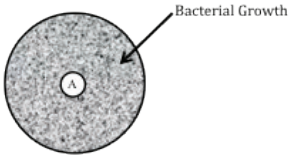
In summary, between 61% and 89% of students were able to answer the assessment questions correctly. The questions that received the highest percentage of correct answers were 3A (89%; describe appearance of *E. coli* on eosin methylene blue [EMB] agar) and 7A (89%; identify zone

of inhibition). The lowest percentages of correct answers were for question 2B (61%; method used to isolate single colonies) and question 4B (63%; what happens if counterstain is not added in a Gram stain).

## DISCUSSION

Our goal was to create a custom, easily accessible, no-cost laboratory manual for our microbiology students

TABLE 2.
Assessment questions and Bloom's taxonomy level.

| Assessment Questions | Bloom's Taxonomy Category |
|---|---|
| 1. Draw and describe the following bacterial morphologies/arrangements: | |
| A. streptococci | Understand |
| B. diplobacilli | Understand |
| 2A. What is the difference between a mixed culture and a pure culture? | Analyze |
| 2B. Name and describe or draw the method used to isolate single colonies. | Remember |
| 3. A patient arrives at a clinic with a urinary tract infection caused by *E. coli*. A urine sample is collected and inoculated onto EMB agar. | |
| A. Describe the expected appearance of the growth on the media. | Remember |
| B. Describe one reason why it is important to use aseptic technique when working with clinical samples | Understand |
| 4A. Name two differences between Gram-positive and Gram-negative cell walls. | Remember |
| 4B. A student prepares Gram stain of *E. coli*, but forgets to add the counterstain. What color would the cells appear? Explain. | Apply |
| 5. A student inoculates an unknown bacterial species onto a TSA slant, and incubates it at 37°C for 24 hours to allow for bacterial growth. She is interested in finding out if the unknown bacteria produces the enzyme catalase. | |
| A. What chemical should the student add to test for this enzyme activity? | Understand |
| B. Describe both the chemical reaction and what the student will see, if the results are **positive**. | Apply |
| 6. You are performing an experiment to determine the temperature requirements of three different bacterial species (A, B and C). You divide 3 agar plates into areas and streak a different bacterial species on each area of the plate. You then incubate the plates at 3 different temperatures (4°C, 37°C and 55°C) and observe them after 1 week. Your results are shown below.   | |
| A. Based on these results, characterize the bacteria based on their temperature requirements using scientific terminology (e.g., mesophile) Bacteria A: _____ Bacteria B: _____ | Analyze |
| B. Which one of these three bacteria would be the most likely to be a human pathogen? **Explain your answer.** | Evaluate |
| 7. You are using a Kirby-Bauer test to determine the sensitivity of Bacteria X to antibiotic A. You observe the following result:   | |
| A. What is the name of the clear area around Antibiotic disk A? | Remember |
| B. Based on these results, do you think Antibiotic A would be a good choice to treat an infection caused by Bacteria X? Explain your answer. | Evaluate |

EMB = eosin methylene blue; TSA = tryptic soy agar.

that was designed with our student population in mind. Our approach was to revise and add new material over the course of several semesters for an easier transition, and to use feedback from students to inform our revisions.

Overall, we achieved our goals—students were satisfied with the lab manual, and we received overwhelmingly positive feedback from our student readers. Our student readers provided invaluable insights, and the student perspective helped us identify several ways to make the text more readable and student-friendly.

We were able to get feedback from a larger number of students by distributing an end-of-semester survey. This type of survey did not provide the same level of detailed review as we received from out student readers, but it did give us additional information from a larger population of students. Although the vast majority of students were satisfied with the introductions and procedures, several (including our student readers) suggested that some of the illustrations needed improvement. Our initial figures were gradually replaced with (1) our own illustrations done by an amateur artist hired for this purpose, (2) our own illustrations done by one of the authors (McLaughlin), and (3) photographs of our own laboratory materials and equipment.

Another area of concern was the online resources—students were less positive about their usefulness. Some wrote that they did not know about them or did not use them. We are currently revising the online resources to include more material from the updated laboratory activities (ELISA, Biolog) and to include additional photographs. Opinions about the usefulness of review questions at the end of each chapter were also somewhat mixed—some students found them very helpful; others said they did not help them prepare for their exams. This difference may be explained by the fact that instructors emphasize different topics. Despite this discrepancy, 75% found the review questions helpful and some students asked for more to be included.

Our students have a clear preference for an OER manual (90%) rather than a commercially available lab manual (3%). A few commented that they were happy to have a manual that was easy to access and download, and that printing could be done at the college for free. The majority (59%) also prefer to download and print themselves; although 31% said they would like a bound copy made available. When asked what topics they would have preferred to have covered in more detail, the most common responses were serial dilution, immunology, eukaryotic microorganisms, and diseases. The request for serial dilution is not surprising, as many students are confused by this technique. We added an appendix to the manual that gives some additional information and practice problems to help students understand this difficult topic. Immunology has been identified as a key concept that nursing students need to understand to succeed in their courses. To address this, we added a simulated ELISA test to the lab exercises. Similarly, we revised our eukaryotic pathogens lab to include more illustrations (simple line drawings) that should help students identify these organisms on their final exams. Although we lack the time to cover additional material, diseases are included in the case studies that are completed during lab 13 and we encourage instructors to make reference to clinical diseases throughout the semester. We plan to continue to assess student understanding of these topics as we increase the variety of supplemental materials.

Results of our lab quiz question assessment are encouraging. The percentage of correct answers ranged from 61% to 89%. It is not surprising that students provided correct answers more often to memory questions than to higher-order questions. It is interesting to note that more students received only partial credit for the questions that asked them to "draw and describe" (1A/B) and "name and describe" (2B) than any of the other questions. One of these questions (2B) also had the lowest number of correct answers (61%). We have noticed that many students answer only one part of a question; perhaps it would be best to list the question components separately to ensure that they are not overlooked. The question with the second lowest number of correct answers (63%) asked for the result if a student performed a Gram stain on *E. coli* but forgot to add the counterstain. This question includes both a memory component (*E. coli* is gram negative) as well as an analysis of the Gram stain procedure. Revision of online resources will include more higher-order questions so that students have additional opportunities to prepare for this type of material.

To date, we have not seen any other descriptions of how formal student feedback has been used in the development/revision of a lab manual. Incorporating student feedback and implementing a stepwise approach to the revision process allowed us to produce a custom laboratory manual that is both user-friendly and easily accessible. Use of an OER manual allows our instructors and other users to readily modify content and adjust procedures based on resource availability. We believe that this approach would be applicable to the development of many other OERs.

## SUPPLEMENTAL MATERIALS

Appendix 1: Student reader contract
Appendix 2: Student evaluation form
Appendix 3: Laboratory exercise student survey
Appendix 4: List of most common suggestions by student readers for lab manual improvement
Appendix 5: Selected quotes from student comments from end-of-year survey

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The authors declare that there are no conflicts of interest.

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