# Faculty Guide: Introducing PHAGES Students to Science Primary Literature

## Overview

The ‘Introducing PHAGES Students to Primary Literature’ set of teaching resources offers faculty 2 distinct sets of teaching resources for introducing students to scientific literature in the classroom. The materials in Teaching Set I guide the students in the reading and analysis of the short form phage therapy research paper, *Engineered bacteriophages for treatment of a patient with a disseminated drug-resistant Mycobacterium abscessus* (Dedrick et al, 2019). Clinical research papers quickly capture the interest of novice researchers and often have accompanying popular media articles and videos that are easy to understand and can be used as an introduction to the topic. The materials in Teaching Set II guide the students in the reading of an early mycobacteriophage paper, *Genome organization and characterization of mycobacteriophage Bxb1* (Mediavilla et al, 2000). This paper includes all of the sections of a traditional research paper and includes laboratory methods familiar to those students working in the Discovery portion of the SEA-PHAGES course.

The learning objectives are ordered by increasing levels of cognitive engagement. Faculty are welcomed and encouraged to adopt those learning objectives appropriate for their student population or desired course outcomes.

## Learning Objectives

1. Explain how scientific communication differs for various audiences
2. Explain why science communication is necessary and important
3. Describe similarities and differences between a research paper and a popular media science article
4. Cite and explain the significance of each section of a research paper
5. Demonstrate strategies for understanding a figure in a scientific paper.
6. Explain the results of an experiment to a peer audience using data from a figure published in a research paper.
7. Derive 3-5 key points from a research article
8. Formulate a series of scientific questions after reading a primary literature article
9. Critically evaluate scientific literature by identifying the limitations of a particular experiment and by proposing alternative interpretations of the results
10. Write a 1-2 page mini-grant proposal that demonstrates an understanding of the process of doing science

## Developing Students at Scientists

Reading and analyzing primary literature is a learned scientific skill. The materials developed provide multiple opportunities for faculty to engage students in elements that may be important for the development of students as scientists. Namely, the use of primary literature in the classroom allows for:

*Explicit DIscussion* - Faculty have the opportunity to explain to students the importance of primary communication as a means of sharing scientific information among scientists. Students can be explicitly told that reading primary literature is a learned scientific skill that takes time to master.

*Instructor Mentorship/Modelling Scientific Thinking* - Paper discussions provide faculty the opportunity to guide students in their understanding of the material but also allow students to see that even faculty/fellow scientists sometimes have questions about a paper or don’t understand every aspect of a paper. Faculty should feel comfortable sharing their own questions with their students.

*Encouraging Perseverance* - The process of learning to read and analyze a primary literature paper can be intimidating to a student but with guidance, students can appreciate the increased knowledge and understanding gained as a result of working through a paper.

*Encouraging Engagement and Enthusiasm* - The reading of primary literature provides an opportunity to directly demonstrate the value and importance of phage research. Simple discussion questions such as, “Would it be possible to repeat this paper with your own phage? What experiments could be similar or different?” begin to challenge students to begin to think of their own work in a broader scientific context.

*Peer Collaboration* - There are multiple opportunities for peer work in the primary literature teaching activities. Students can work in groups when analyzing and/or presenting paper figures and students and faculty can share ideas in full class discussions.

### Teaching Set I

The primary literature paper featured in this set of teaching resources is *Engineered bacteriophages for treatment of a patient with disseminated drug-resistant Mycobacterium abscessus* (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6557439/>) (Dedrick, et al. 2019). This paper from the Hatfull laboratory describes the development of a therapeutic phage cocktail to treat a life-threatening infection in a 15-year old cystic fibrosis patient. Some phages included in the cocktail were originally isolated by students. The Hatfull lab uses plaque assays and spot tests to identify mycobacteriophages that are effective against the clinical bacteria strain. The group also converts two phages, BPs and ZoeJ, from temperate to lytic using BRED recombineering to delete the immunity repressor genes.

#### Resources for Teaching Set I Include:

* Popular Media Article:  [Genetically modified virus saves teen's life, offers hope in fight against antibiotic resistance](https://www.cnn.com/2019/05/09/health/cystic-fibrosis-teen-engineered-bacteriophage-study/index.html)
* Popular Media Video (CNN video associated with text article)
* Science Communication Question Set
* Primary Literature Article: *Engineered bacteriophages for treatment of a patient with a disseminated drug-resistant Mycobacterium abscessus*
* Dedrick et al, 2019 Background Information Slide Set (ppt)
* Dedrick et al, 2019 Questions - This document contains a series of guiding questions with supporting information to assist students in their reading of the paper. Students are encouraged to write out their responses to the questions to allow for a richer in-class discussion.
* Dedrick et al, 2019 Figures (ppt) - This document contains annotated figures and can be used by students or faculty to prepare for the presentation of the paper figures in a journal club-like class discussion.

Teaching Set 1 introduces students to basic forms of science communication and uses a clinical research article to introduce students to the primary literature. A suggested structure for using the resources in Teaching Set I is outlined below:

1. **Out of class assignment:** Students read the CNN popular media article that was written and produced using information and interviews from the Dedrick paper and Hatfull lab. There is an accompanying short CNN news video that accompanies the reading that students should also view. Students complete the ‘Science Communication Question Set’ while reading the CNN article and viewing the accompanying video. The Question Set has students reflect on the principle reasons for broad science communication and provide guiding questions for a class discussion.
2. **In-class Discussion:** Faculty and students have a discussion about the CNN article and the accompanying video using the ‘Science Communication Question Set’ as a guide for the discussion.
3. **In-class Lecture:** Faculty explains some of the background information necessary to understand the Dedrick et al, 2019 paper using the ‘Dedrick et al, 2019 Background Information slide set.’
4. **Out of class assignment:**  Students are assigned sections of or the entire Dedrick et al., 2019 paper to read. Students should complete the ‘Dedrick et al, 2019 Guiding Question Set’ while reading
5. **In-class Discussion:** The faculty assigns one or more figures to groups of students to prepare for a group discussion. Students use their responses from the ‘Dedrick et al, 2019 Guiding Question Set’ and information in the ‘Dedrick et al, 2019 Figures’ ppt to prepare a figure for presentation to the group. To walk students through the process of analyzing a figure in a research paper, important information has already been included on the slide for each figure. Students should be encouraged to be sure they understand the figure and mark-up the figure with arrows, circles, text to highlight important features or data elements. Student groups then present the figures to the class in the form of a journal club-style discussion either the same day or on a separate day depending on time.
6. **Follow-Up Activity:** Students first watch the iBiology video ‘Phage Therapy’ by Paul Turner (Yale) <https://www.youtube.com/watch?v=xvC8xME5Zrg&feature=youtu.be>. The class then engages in a discussion that compares new information learned from watching the video to data presented in the Dedrick et al, 2019 paper. Guiding questions could include, “Were there any ‘loose ends’ in the Dedrick et al, 2019 paper that can be explained by the information presented in the Turner iBiology talk? After hearing the new information in the Turner iBiology talk, are there are additional scientific questions to be answered? How might one go about addressing those questions?”

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### Teaching Set II

The primary literature paper featured in this set of teaching resources is *Genome organization and characterization of mycobacteriophage Bxb1* (<https://onlinelibrary.wiley.com/doi/epdf/10.1046/j.1365-2958.2000.02183.x>) (Mediavilla et al., 2000). This paper from the Hatfull laboratory describes the isolation and characterization of the mycobacteriophage Bxb1 and compares Bxb1 to two previously characterized phages L5 and D29. The materials and methods used in the paper will be familiar to students in the Discovery portion of the SEA-PHAGES course. The paper provides an opportunity to discuss phage immunity and preview basic concepts revisited in the *In Silico* portion of the course. To reinforce the notion that science builds upon previous knowledge and to encourage students to begin thinking independently, an extension activity was developed in which students write a one-page ‘grant’ and participate in an anonymous grant review session to facilitate class discussion.

#### Resources for Teaching Set II Include:

* Short click-and-learn module: ‘An Introduction to Scientific Communication’
* Reading a Scientific Paper Slide Set (ppt)
* Mediavilla et al., 2000 Introduction Questions
* Mediavilla et al., 2000 Figure-Results Questions
* Mediavilla et al., 2000 Discussion Assignment
* Mediavilla et al., 2000 Figures Slide Set (ppt)
* Mini-Grant Assignment
* Mini-Grant Rubric

A suggested structure for using the resources in Teaching Set II is outlined below:

1. **Out of class assignment:**  Students complete the brief “An Introduction to Science Communication” click and learn module
2. **In-class Lecture:** Faculty use the slide set ‘Reading a Scientific Paper’ to introduce students to sections of a primary literature research paper and to briefly introduce the Bxb1 paper.
3. **Out of class assignment:** Faculty assign a portion of or all of the Introduction Questions for students to read. There is a significant amount of new knowledge for new student researchers to grasp in the Introduction so faculty may want to consider dedicating two discussion sessions to the Introduction of the paper.
4. **In-class Discussion:** Faculty and students have a discussion about the assigned Introduction questions. This is an excellent opportunity to make connections to work the students may complete in the SEA-PHAGES Discovery or *In Silico* courses. Faculty may want to consider breaking up the assigned Introduction Questions so that the Introduction of the paper is discussed over two class sessions, depending on time.
5. **Out of class assignment:**  Students are assigned sections of or the entire Mediavilla et al., 2000 paper to read. Students should complete the ‘Mediavilla et al., 2000 Figure-Results Question Set’ while reading.
6. **In-class Discussion:** The faculty assigns one or more figures to groups of students to prepare for a group discussion. Students use their responses from the ‘Mediavilla et al., 2000 Figure-Results Questions’ and information in the ‘Mediavilla et al., 2000 Figures’ ppt to prepare a figure for presentation to the group. To walk students through the process of analyzing a figure in a research paper, important information has already been included on the slide for each figure. Students should be encouraged to be sure they understand the figure and mark-up the figure with arrows, circles, text to highlight important features or data elements. Student groups then present the figures to the class in the form of a journal club-style discussion either the same day or on a separate day depending on time.
7. **Out of class assignment:**  Students complete the Mediavilla et al., 2000 Discussion Assignment and briefly summarize 5 major concepts that they feel were the important take-away messages from the paper.
8. **In-class Discussion:** Faculty and students compare and discuss the important take-home messages after reading the paper. This discussion is also an opportunity for the group to compare and contrast observations noted in the paper for Bxb1, D29, and L5 with their own isolated phages.
9. **Follow-Up Activity:** Students complete the Grant Panel Assignment. This activity asks the students to consider “What would you do next?” after reading the Mediavilla et al., 2000 paper.This short writing assignment encourages students to begin thinking about experimental questions and experimental design. As an extension of the activity, students turn in the grant anonymously. The faculty member sorts the class into 2-4 groups and redistributes grants to each group for review. In the anonymous review, the groups read the proposals of their peers and provide feedback using the ‘Grant Panel Rubric.’ This activity provides a low-entry opportunity for students to participate in the review process and generates additional discussion about the qualities of a grant proposal. This activity was adopted after a teaching development seminar with Sally Hoskins and is adapted from the CREATE approach (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3228655/pdf/368.pdf>).

For faculty interested in a more advanced study of the primary literature with their students, the 3-paper series (Mediavilla, et al 200X, Kim et al, 200X, and Ojha, et al, 200X) offers the opportunity to show students how research builds on itself and how the discussion section of a paper advances as the body of research grows. The teaching resources included below were designed to reflect the increasing ability of students to read and understand primary literature as they gain experience. The 3 papers are all from the Hatfull lab.

* Kim et al, 2003 Introduction Questions
* Kim et al, 2003 Figures and Results Questions
* Kim et al, 2003 PPT Slides
* Kim et al, 2003 Discussion Questions
* Ojha et al., 2005 Background PPT Slides
* Ojha et al., 2005 Questions
* Ojha et al., 2005 Figures PPT

**Assessment**

Reading the primary literature is a process that takes time and practice. To assess a student’s effort, faculty can choose to collect student responses to the question sets and grade accordingly. Faculty can also assess students based on preparedness and participation in group discussions. A short quiz or short-answer response question set could be used to assess content knowledge after the class has read and discussed the paper.