**Project Title:** *Phage Comparative Genomics Lab Manual*

**Authors and Affiliations:**

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| **Author** | **Affiliation** |
| **Andrew Kapinos** | **UCLA** |
| **Canela Torres** | **UCLA** |
| **Amanda C. Freise** | **UCLA** |

**Keywords:** *Comparative genomics, dot plots, Phamerator maps, gene content similarity, phylogenetic tree*

**Description:** *A lab manual containing detailed instructions for several bioinformatics tools, all of which enable students to perform comparative genomic analyses. The tools are easy and straightforward to use, and will be recognizable by students as they are some of the most common tools used in phage comparative genomics literature. These tools are also accessible by students either in the web browser or via widely available downloadable software, so the tools can be used either in person or for remote learning.*

**Learning objectives:**

After completing this module, students should be able to:

* *Understand how comparative genomic analysis enables insight into phage diversity.*
* *Develop novel research questions about phage genomic similarity and dissimilarity.*
* *Use a variety of tools to answer their questions.*
* *Perform qualitative and/or quantitative analysis of several types of genomic data.*
* *Produce annotated data figures suitable for papers and oral presentations.*
* *Use the scientific method to develop, test, and revise experimental hypotheses.*

**How is the module structured to promote student development as a scientist?**

This set of modules gives students multiple opportunities to develop project ownership of content, science identity, and self-efficacy though the creation and testing of their own research questions. Students will also be encouraged to perservere though troubleshooting programs and making sense of their analysis. Being able to do comparative genomics analysis on real phage genomes will encourage engagement and enthusiasm among students.

**Intended Teaching Setting**

**Course level:** Non-majors, majors, first-year students, and upper division students. For more advanced students, multiple tools can be introduced. For less advanced students, recommend using just 1-2 tools depending on time available.

**Instructional Setting:** in-person classroom or online

**Implementation Time Frame:** approximately 3-8 hours per tool, from question development to finished, annotated figure. Additional time needed for students to revise and redo analyses. Using small datasets (e.g. comparing just a few phages versus many phages) will decrease the amount of time involved.

**Acknowledgments:**

*Thank you to Drs. Jordan Moberg Parker and Erin Sanders O’Leary for laying the groundwork on teaching materials for these tools. Thank you to Chris Dao for the section on Phylogeny.fr, as well as Rinah Kim and Elizabeth Vanderwall for the section on CodonW.*

*Many thanks to the fantastic SEA-PHAGES bioinformatics team for their scientific support: Drs. Welkin H. Pope, Debbie Jacobs-Sera, Daniel A. Russell, Steven G. Cresawn, and Graham F. Hatfull.*

*This manual will be updated periodically. Changes will be noted at the bottom of the manual in the Change Log.*

*Suggestions, comments, and corrections are welcome at afreise@ucla.edu.*

**Project Documents**

**Facilitator documents:**

* *Phage Comparative Genomics Lab Manual\_Teaching Notes.docx*
* *Presentations and videos, linked on Youtube and Google Drive:*
  + [**Formulating a Research Question**](https://drive.google.com/file/d/1GW8NZOfCOYTi_cTdgQagiJS0ha5BxNwo/view?usp=sharing) **(Slides)**
  + [**Asking Research Questions, Constructing Hypotheses, BLASTn Searches, and Downloading/Using Gepard**](https://youtu.be/gz5e60-T2gg) **(Video Tutorial)**
  + [**Guide to “Since, If, Then” Hypotheses**](https://docs.google.com/presentation/d/1jw_LTPGy3-WxWpyZl9h2M9CWzf4YwkuUwaHrQZJLcYg/edit?usp=sharing) **(Slides)**
  + [**Creating and Formatting Figures**](https://docs.google.com/presentation/d/1aMeA6cpHO_HW5iYb8CgawIbNfyxDF0gP8XOkhHNEESs/edit?usp=sharing) **(Slides)**
  + [**Annotating Dotplots**](https://docs.google.com/presentation/d/1ueC3pi3ymCNykZE0CDPShlohR1yJpo-JBu9m3jqE_fM/edit?usp=sharing) **(Slides)**
  + [**Introduction to Phylogenetic Trees**](https://docs.google.com/presentation/d/1gRs-pBnTSlo-spqbJw0aTZiATWviG477y-8J1qJfYKM/edit?usp=sharing) **(Slides)**
  + [**PhagesDB Explore Gene Content; Making Publication-Quality Heatmaps in Excel**](https://youtu.be/nTDJjhjVMLQ) **(Video Tutorial)**
  + [**Introduction to OrthoANIu**](https://docs.google.com/presentation/d/1_HadMGXnkSvrltM7f3d9slVGUtOq-Lvar0zkuLxE1gA/edit?usp=sharing) **(Slides)**

**Learning activity document:** *Phage Comparative Genomics Lab Manual. Access online as a live* [*Google Doc*](https://docs.google.com/document/d/1wINS53ORokW-9gDTN9FLfc1GfHftchGN/edit?usp=sharing&ouid=112209090980686611264&rtpof=true&sd=true)*.*

**Assessment document(s):** *N/A.*