The Phage Genomics Research Program - Authentic Research for First Year Students

Aaron Best  
Hope College, best@hope.edu

Joseph Stukey  
Hope College

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The Phage Genomics Research Program – Authentic Research for First Year Students

Dr. Aaron A. Best and Dr. Joseph Stukey
Department of Biology, Hope College

I. Abstract
The Hope College Department of Biology is entering its 9th year of the Phage Genomics Research Honors Laboratory course offered to first-year college students as an alternative to the standard Hope College Introductory Biology lab. This course is part of a national experiment to improve education in the sciences led by the Howard Hughes Medical Institute; Hope College was selected as one of 12 institutions nationwide to pilot this program. Students for the honors laboratory course at Hope College were selected from a restricted pool of applicants earning high scores on the ACT and SAT college entrance exams and showing an interest in science. Lab sessions ran twice a week for a total of 5 hours in the fall (phageDNA isolation semester) and 4 hours in the spring (bioinformatics week). In the fall students worked independently and presented their findings in research article style written in groups. Students were expected to learn three or four, analyzed the sequenced genome, and highlighted their findings in student-driven journal articles and oral presentations. During the first 5 years of the program, 98 of 99 students successfully isolated novel mycobacteriophage from the Holland area and 11 of the phage genomes have been sequenced. The HHMI course outline has been supplemented with additional laboratory and analysis skills during the fall semester based on subject matter covered in the standard Hope College Introductory Biology core course. This included statistical analysis (phage plaque size) and microscopy (differential staining of the host strain, biofilm assessment). During the spring semester students have been introduced to computer programming and bioinformatic databases through a series of individual and group assignments. The phage program has been highly successful for recruitment and retention of high quality students to Hope College, the Division of Natural and Applied Sciences, and the Department of Biology.

II. Introduction

A. HHMI Science Education Alliance
- Enhance undergraduate education in sciences
- Target incoming first-year students
- Immense student-year-long authentic research experience
- Hope College’s one of original 12 institutions selected to participate from across the nation, now expanded to ~80 institutions
- Applicants with ACT Science Subject Score ≥ 30 and Indicating some interest in a science (any discipline) invited to apply to the Hope College Phage Program

B. Mycobacteriophage Biology and Genomics
- Microbes spread across the world, affecting 1/3 of population worldwide
- Bacteria are infected by viruses called phage
- Phage allow for study of mycobacteria through enhanced genetics, understanding of how phage contribute to bacterial biological processes
- Full genome sequences of phage reveal novel functions, genes, and evolution of mycobacterial plagues and hosts

III. Phage Genomics Research Course Overview

Goals for the Program
Create unique laboratory based experience for first year students conducting authentic research
Create cohorts of high quality students within Department and Division
Increase recruitment and retention of students into Biology and STEM fields

Outline of Laboratory-based Course
- Students collect, process and prepare, isolate plaque
- Prepare purified phage lysate stock
- Isolate & purify phage genomic DNA
- Assemble phage genomic DNA
- Submit phage genomic DNA for sequencing
- Predict and call phage gene
- Annotated gene calls
- Family determination and comparative analysis
- Examination of results

Vignette: GRAND CHALLENGE - How do you focus sequencing efforts on finding truly novel phage?

PHID: Phage Identification of New Digests. A Java program written to autonomously give list of possible phage (Kat Deeg, 2012)

IV. Outcomes of Hope College Phage Program

Student Achievements
Publications: 3 in peer-reviewed journals from phage program
Presentations: Numerous student presentations at local, regional, and national scientific meetings – oral and poster
Awards:
- Goldwater Scholarship Awards and Honorable Mentions
- NSF Graduate Fellowship
- Beckman Research Scholar Awards
- ASM Undergraduate Research Fellowship
- HHMI EXROP Award
- Multiple external Summer Research Program awards
- Conference presentation awards for best poster/completed presentations

Impacting Students
Propels students toward leadership in the division
- Inspires early and sustained participation in research programs
- Forges lasting relationships among students – cohort building

Impacting Hope College
Creates new learning communities at Hope College
- Strengthens national reputation as a leader in science education
- Attracts high quality students to Hope College
- Extends beyond the discipline of Biology to all STEM fields
- Yields new research, collaboration, and funding opportunities
- Encourages development of phage-like research courses throughout the division
- Provides a model for extending authentic research experiences to a broader student population

Cohort Comparison:
- 2008-2009
- 2009-2010
- 2010-2011
- 2011-2012
- 2012-2013

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Dr. Aaron A. Best
Department of Biology, Hope College
best@hope.edu

Table 1: Comparison of Cohorts
<table>
<thead>
<tr>
<th>Year</th>
<th>Hope College All Students</th>
<th>Hope College Students with Science ACT ≥ 230</th>
<th>Phage Program Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>76%</td>
<td>84%</td>
<td>83%</td>
</tr>
<tr>
<td>2009</td>
<td>76%</td>
<td>84%</td>
<td>83%</td>
</tr>
</tbody>
</table>

*Calculated based on four year fall enrollment rates

Phage Program Students Declare STEM Majors

<table>
<thead>
<tr>
<th>Year</th>
<th>Biology and BMB</th>
<th>Physics and Astronomy</th>
<th>Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>16%</td>
<td>20%</td>
<td>10%</td>
</tr>
<tr>
<td>2009</td>
<td>20%</td>
<td>16%</td>
<td>10%</td>
</tr>
</tbody>
</table>

*Declared majors for cohorts 2nd year – not all students may have declared

Figure adapted from Inventum G.F., phamilies.

Figure 1: A tree representing the relationships of 60 sequenced phage

Figure 2: Boxplot showing the distribution of fragment size across phage families

Figure 3: Scatter plot of DNA quality vs. sequencing coverage

Figure 4: Heatmap showing the clustering of phage families

Figure 5: Violin plot of standard deviation of fragment size across phage families