Bringing Authentic Genomics Research into the Classroom: Analysis of Maize Stress Response

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Many of the Inquiries Do Not Involve Research and Are Targeted to Upper Level Students

In 1993, only 10% of the responding schools reported an investigation-based laboratory curriculum
In 2005, over 70% of schools use investigation-based labs.

Sundberg et al., 2005

“Big Data” Analysis is Essential Part of Today’s Training

Data Scientists are “the sexiest jobs of the 21st century” (Davenport and Patil, 2012)
Computational skills are lacking in many areas (reviewed in Feser et al., 2013)
Concerted effort to infuse computational and mathematical training into Biology courses is under way (Marsteller, 2010; CBE, 2010:9 volume)

DNA Learning Center (CSHL): Workshops

11 Faculty from different Colleges and Universities
Top of the line training in RNA-Seq data analysis
Incorporating RNA-seq data analysis into classroom
Assessing the quality of the programs

DNA Subway: Green Line - Introduction to RNA-Seq Analysis for Undergraduate Students
Training Students in Analyzing “Big Data”: Response of Maize Seedlings to Cold

- Characterize phenotypic and transcriptional variation in maize response to cold
- Find factors that contribute to cold resistance
- Investigate cold “priming” / “hardening”
- Incorporate elements of “big data” analysis into student training

Maize is the most widely grown grain crop in the Americas, with over 350 million metric tons grown annually in the United States alone (USDA, 2013).

Series of Laboratory Exercises

- Understand of the RNA-Seq analysis
  - What scientific questions can be answered using this approach?
  - What data are collected?
  - How does the “wet lab” stage work?
- Get involved in data analysis
  - Data quality - Green Line / Subway
  - Read alignment and counts - Green Line / Subway
  - Differentially expressed genes - DE-Seq
- Introductory Genetics Course (100 students)
  - Completing team projects as inquiry-based active learning activities to learn about RNA-Seq analysis
  - Primary literature analysis
  - Data analysis and graphical representation

Questions

✓ Now you are scientists who study maize cold response
✓ What questions would you like to ask and what types of experiments would you like to run to address these questions?

- What genes are affected by stress response?
- What biochemical pathways are activated in response to stress?
- What genes respond differently between Mo17 and B73 to provide Mo17 with the tolerance to cold?
- Can we find specific genes that confer resistance and what is the function of these genes?
- What genes are activated in response to any stress?
Alignment of Sequence Reads: Can You Do It?

<table>
<thead>
<tr>
<th>Genes:</th>
<th>TTTTGTTCAGATCGATCAGTACGTA</th>
<th>GACTGGACTAGGGCATATCGACAT</th>
</tr>
</thead>
</table>

Sequence reads:
- TTAAGT
- CGACAT
- TGATCG
- TTAGTA
- GATCGA
- GTAGCAT
- CGACAT
- AGGGCA
- GGGCAT
- CAGTAC
- GACTAGG
- TCAGA

Imagine we have 30M 100 bp reads in both directions (with some SNPs) in a 3 billion bp genome.

Students Develop Their Hypotheses / Expectations for Differential Gene Expression

- What proportion of maize genes (~40,000 predicted high confidence genes) would you expect to be expressed in maize 14 day old seedlings?
- What proportion of maize genes you would expect to respond to cold?
- What groups of maize genes you would expect to be down-regulated in response to cold stress?
- What types of maize genes would predict to show no response to stress exposure?
- What types of maize genes would likely be activated in response to stress?

Student Results

Different inbreds respond to stress similarly.

Student Results

What Else Can We Do?

- Finding interesting genes and RT-PCR validation
- Extension to other lines
- Investigating priming

So What did Students Learn?

- Content assessment
  - 10 RNA-Seq questions
  - Data interpretation and conceptual questions
- CURE Assessment (Lopatto et al., 2008)
  - Student self-assessment of research-related techniques
- Student Evaluations
  - "Doing real research in class is really cool"
  - "I never realized that biology is almost computer science now..."

What did I Tell You Today?

- Doing authentic research with students is possible
  - Intro course
  - Positive student comments
  - Real results
  - Learning gains
- Long-term series of exercises introducing students to various approaches to analysis of a biological phenomenon
  - Global transcriptional genome response to stress
  - Identifying factors controlling genomic variation to stress response
Thank You

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My Biology Colleagues

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DNA Learning Center (CSHL)