Boosting Yeast's Appetite for Sugars: Analyzing Biofuels Fermentation Data

Overview: Can microbiologists engineer new strains of yeast to produce more biofuel from the same amount of plant biomass? In this GLBRC *Data Dive*, students learn about how scientists Trey Sato and Audrey Gasch are using directed evolution techniques to create mutant yeast strains that can ferment all of the sugars in plan biomass, not just the glucose. Students analyze a data set from one of the scientist's fermentation experiments to determine how a new mutant yeast strain performs compared to a standard yeast variety.

Levels
High School (9-12)

Subjects
Environmental Science, Biology, Biotechnology, Microbiology

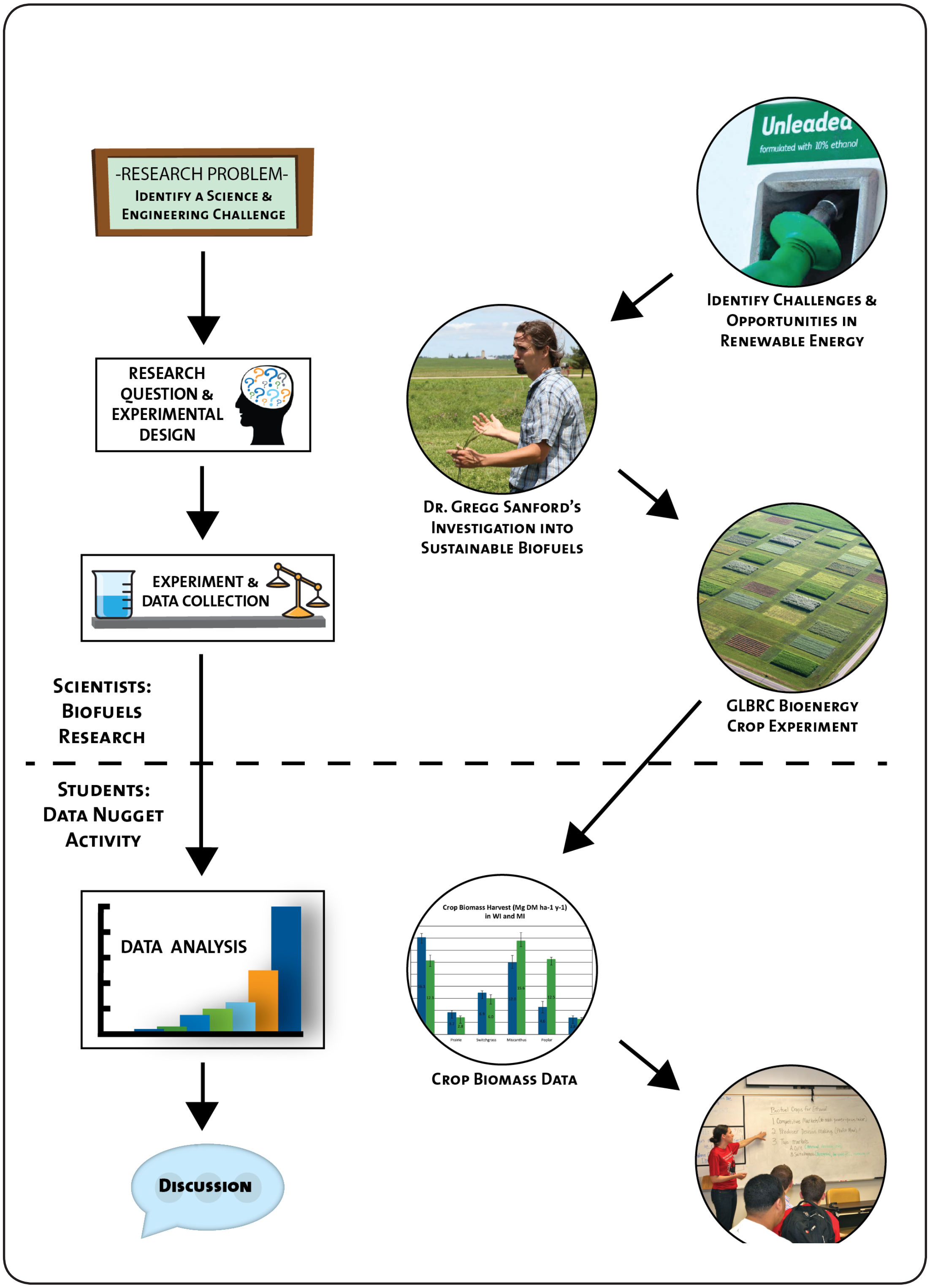
Objectives
- Identify the scientific questions, hypothesis and variables in a biofuels fermentation experiment
- Analyze and interpret data on xylose and ethanol changes over time in a fermentation experiment
- Construct an argument based on evidence evaluating the effectiveness of a new mutant yeast strain's ability to make ethanol from xylose

Materials
Boosting Yeast's Appetite for Sugars Data Dive Activity Package

Activity Time
One 50-minute class period

Standards
Next Generation Science Standards (2013)
- Scientific Practices: analyzing and interpreting data; engaging in argument from evidence
- Disciplinary Core Ideas: from molecules to organisms: heredity: biological evolution
- Crosscutting Concepts: scale, proportion, and quantity; energy and matter; cause and effect
- Performance Expectations: See page 3 for details

NGSS Lead States. 2013. Next Generation Science Standards: For States by States. Washington DC: The National Academies Press



GLBRC Data Dive: Boosting Yeast's Appetite for Sugars

Overview: Can microbiologists engineer new strains of yeast to produce more biofuel from the same amount of plant biomass? In this GLBRC *Data Dive*, students learn about how scientists like Trey Sato and Audrey Gasch are using directed evolution techniques to create mutant yeast strains that can ferment all of the sugars in plan biomass, not just the glucose. Students analyze a data set from one of the scientist's fermentation experiments to determine how a new mutant yeast strain performs compared to a standard yeast variety.

Learning Outcomes: Students will…

- Identify the scientific questions, hypothesis and variables in a GLBRC fermentation experiment
- Analyze and interpret data on xylose and ethanol changes over time in a fermentation experiment
- Construct an argument based on evidence evaluating the effectiveness of a new mutant yeast strain's ability to make ethanol from xylose

Prior Knowledge: This lesson assumes some basic knowledge of genetics, chemistry and natural selection. Familiarity with the process of fermentation is helpful. This lesson also assumes some familiarity with the scientific method, hypothesis testing, graphing (if students are asked to create their own), and graph interpretation. For helpful resources on covering these concepts see: http://datanuggets.org/concepts-to-cover-before-introducing-nuggets/

Standards

Next Generation Science Standards (2013)

Performance Expectations

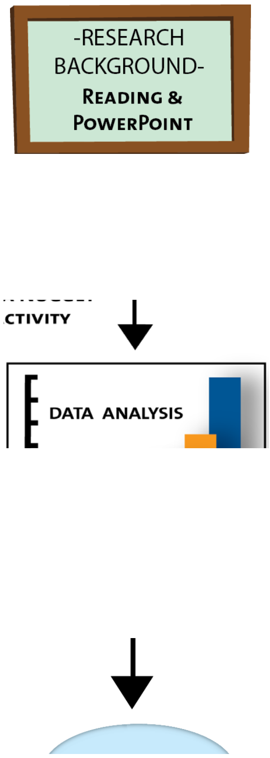
Middle School:

- **MS-LS1-5**. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
- **MS-LS4-4.** Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.

High School:

- **HS-LS3-3.** Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.
- **HS-LS4-3.** Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.

Scientific and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and interpreting data Engaging in argument from evidence	**LS1**: From molecules to organisms: Structure and process **LS3**: Heredity: Inheritance and variation of traits **LS4**: Biological evolution: Unity and diversity	Cause and effect Scale, proportion, and quantity Energy and matter: Flows, cycles, and conservation



Activity Sequence:

1. Read and discuss the Research Background as a class. Have students identify the scientific question driving the experiment and underline the hypothesis in the text.
3. Discuss answers as a class and use the accompanying presentation slides, as needed, to review the research methods.
4. Hand out worksheets with the appropriate graph level for your students as described below.
   a. Type A: data displayed on graph; axis labels and scale provided
   b. Type B: students graph data; axis labels and scale provided
   c. Type C: students graph data; axis labels and scale not provided
5. Have students identify independent and dependent variables.
6. Share graphs and discuss answers as a class. In constructing a scientific argument, it is important for students to pinpoint specific numbers, trends and differences in the data to support their statements.
7. Discuss possible next steps for this research and research methods and sources of information to answer those questions.

Extensions & Variations:

1. Advanced students can conduct their own data analysis of this experiment or other related research questions using the spreadsheet included in "Supplemental Materials."
2. Read "A Modern Scientist-Engineer in the World of Fermentation," a research story about how researchers studying fermentation through history have applied science and engineering practices` to solve problems.
3. Conduct the Fermentation in a Bag investigation comparing simple sugars like sucrose, glucose, and xylose as the food source for yeast.
4. Conduct the Fermentation Challenge investigation to discover different fermentation rates of feedstocks and why some carbohydrates are easily fermented by yeast while others are not.
5. Have students conduct their own fermentation experiment through CB2E: Converting Cellulosic Biomass to Ethanol by investigating the process of converting cellulosic biomass into sugars (glucose) and then into ethanol.
6. Model natural selection of yeast using an online simulation or hands-on

activity. Have students select a new mutant color which represents xylose fermentation ability. Make observations and explanations about how the frequency of mutants changes in successive generations.

Additional Resources:

- **The GLBRC Education and Outreach site** has a collection of many other high-quality instructional materials to explore dimensions of producing and using biofuels appropriate for a range of K-12 STEM subjects and content areas. See: https://www.glbrc.org/education/classroom-materials.
- **The MSU Data Nuggets site** has many helpful resources for teachers, including materials for introducing students to the scientific method, scientific argumentation and basic statistics. See: http://datanuggets.org/
- **Reference article:** This data was published in a different form in the following scientific article:
  Parreiras LS, Breuer RJ, Avanasi Narasimhan R, Higbee AJ, La Reau A, Tremaine M, et al. (2014) Engineering and Two-Stage Evolution of a Lignocellulosic Hydrolysate-Tolerant Saccharomyces cerevisiae Strain for Anaerobic Fermentation of Xylose from AFEX Pretreated Corn Stover. PLoS ONE 9(9): e107499. doi:10.1371/journal.pone.0107499

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