Using the Open Science Data Repository to Explore Human Anatomy & Physiology

Curricular Unit
Teacher Materials

OVERVIEW

Students will read scientific articles, learn basics about space biology, and explore omics data to learn how genes are changed in different environments. The students will then assess WHY they might be seeing trends in differentially expressed genes.

Students will best be able to complete this unit once that have had a basic biology course. Relevant topics include transcription, translation, and basic human anatomy.

CONTENT OBJECTIVES

- Students will be able to identify important information within a scientific article.
- Students will be able to apply their personal knowledge and experience to a real scenario and use data to back up a claim.
- Students will make predictions about WHY differentially expressed genes may be occurring and the physiological significance for the organism.

PACING AND SCHEDULING

This unit was designed to span approximately 4-5 class periods. This may work for either traditional (55-minute) or block (90-minute) schedules as unfinished work may be taken as homework each day.

TEACHING METHODS

- **Direct instruction to precede? unit:** Basic space biology and its connection to human anatomy and aging. Instruction should include typical aging effects that are often seen in astronauts**.**
- **Whole Class Discussion:** Space biology, gene expression, and other relevant student questions.
- **Computer interaction:** Use of usegalaxy.org, osdr.nasa.gov, genecards.org. Students need access to PowerPoint, Google Slides, or equivalent. Internet connectivity required.
- **Small group work:** Student groups read a scientific article, work through gene.Cards.org to create predictions, and create a short presentation.
- **Presenting/communication:** Students present their findings to the class and answer questions.

CURRICULAR CONTENT

Day 1: Teacher goes through direct instruction/discussion on space biology, why it matters for understanding human anatomy/physiology, and how it can be related to aging. Space biology can be used as a valuable tool to assess human aging effects. Lead students to make connections to changes in physiology and gene expression. Introduce GeneLab and the Open Science Data Repository and how to navigate.

-Enumerate 3 – 4 major effects of spaceflight on the human body and why they matter to the system.

Day 2: Assign small groups (of ~3-4 students/group) and a biological question to each group. Allow the rest of the class period to find a paper and read it. Guide students in how to read a scientific paper, per discretion of the instructor.

Scientific article suggestions:

- Read in this order: Abstract, Introduction, Discussion, Methods/Results.
- If feasible, print the article and summarize each paragraph in the margin.
- Have students web search any unfamiliar terms
- Additional link on rules to reading a scientific article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7392212/

Students complete reading as homework if not finished during class.

Sample question/phrase to assign:

- "How is bone mass changed in space? What disease(s) does this mimic/cause?"
  - Preferred answer: mass/density decreases, change in ratio of osteoclasts: osteoblasts, like osteoporosis and related conditions
  - Optional dataset(s): OSD-664 (phenotypic data only), OSD-467 (Data processing request submitted; document will be updated upon completion.)
- "How do the effects of spaceflight mimic ageing?"
  - Preferred answer: Any condition in which vision is impaired and intracranial pressure changes, bone and muscle atrophy/loss of density, onset of age-related diseases
  - Optional dataset(s): OSD-580, OSD-247, OSD-373, OSD-457, OSD-162
- "How do muscles change during spaceflight? Do similar effects ever occur on Earth?"
  - Preferred answer: muscle mass decreases as load (body weight) is removed and continues for the duration of spaceflight. Similar conditions in immobile individuals (wheelchair, bedrest, etc.). To a lesser degree, when someone has to avoid using a limb after an injury when it is in cast
  - Optional dataset(s): OSD-247, OSD-580, OSD-244
- "How can fruit flies be useful in understanding human physiology in space?"
  - Preferred answer: immune response, digestive/nervous systems, etc.
  - Optional dataset(s): OSD-588, OSD-207
- "How are microbes/yeast useful for understanding human physiology?"
  - Preferred answer: cellular processes, microbiome, etc.
  - Optional dataset(s): OSD-254
- "If you don't use it, you lose it"
  - Preferred answer: atrophy of bone, muscle, any unused cells are broken down/recycled

- Optional dataset(s): OSD-207
- "Form Follows Function"
  - Preferred answer: anything that indicates the shape/structure is dictated by its job/function. It was designed evolutionarily based on necessary function.
  - o Optional dataset(s): OSD-207, OSD-247, OSD-580, OSD-244
- "The mitochondria is the powerhouse of the cell"
  - Preferred answer: mitochondria create ATP/energy that fuels all cellular processes.
  - Optional dataset(s): OSD-457

*To find additional available studies with transcriptomic datasets, navigate to https://genelab.nasa.gov/latestdatareleases/transcriptomics

Day 3 (Two instructional options)

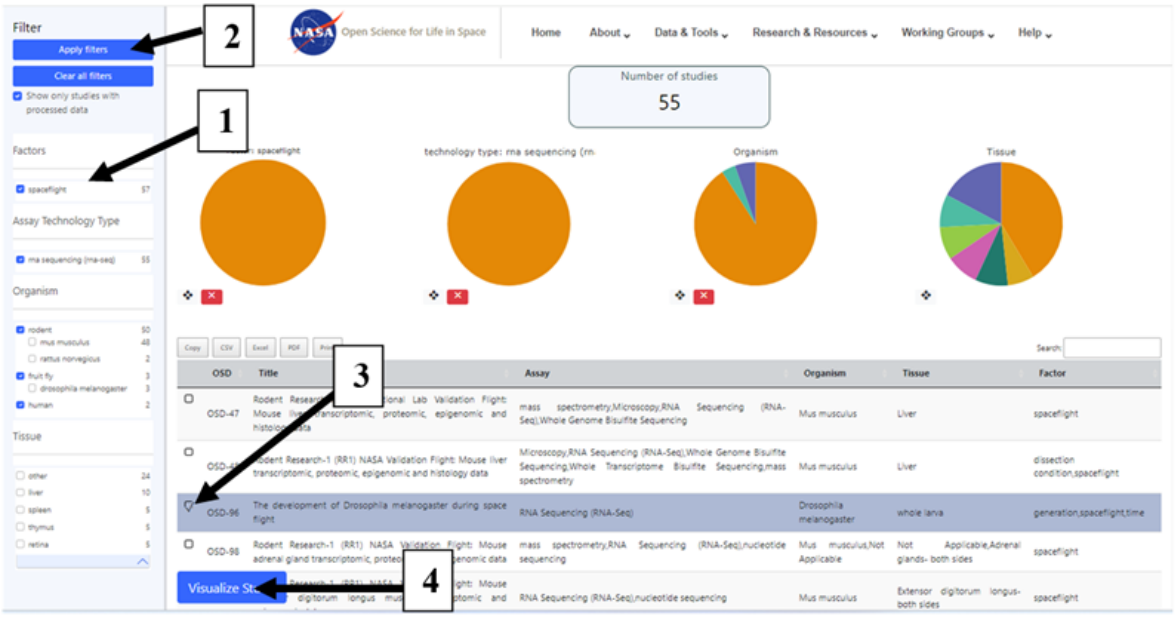
Option 1: Start class with each group sharing (verbally) their prompt, what their paper was about, and the evidence from the paper that helps explain the assigned question/phrase. Each group should only take a few minutes. Have students create Galaxy accounts. Supply COUNTS files and have the students run the **DESeq2, Filter, Annotate DESeq2/DEXSeq**, and **Volcano Plot** tools. They should label the 5 most DE genes. Demonstrate the steps with a practice set as the students go through the same steps. This will ensure all students can complete the volcano plot the same day. See the *GeneLab for High Schools Bioinformatics Manual* Exercises 15-17 on pages 65-75 (2024 version) for step-by-step instructions on using these tools.

Requests for access to the bioinformatics manual can be made to arc-gl4hs@mail.nasa.gov
Datasets for listed OSDR studies may be imported to personal Galaxy accounts from links in the "References to Datasets" section at the end of this document.

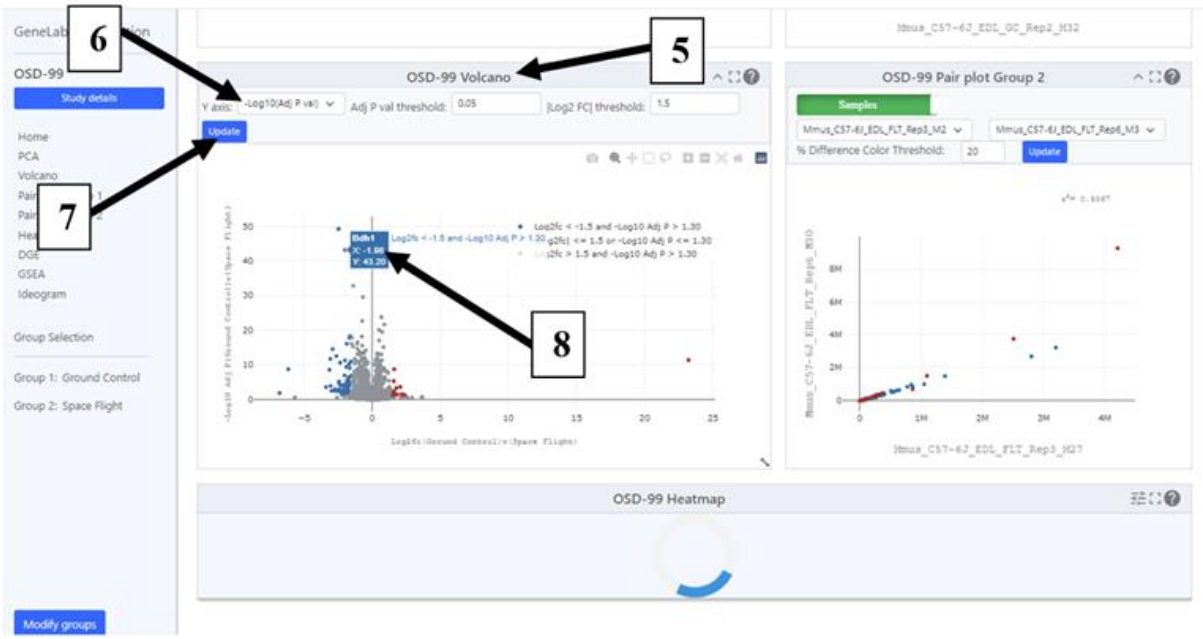
*When reviewing the datasets, note that discrepancies may occur between the description and title due to samples obtained through programs like BSP or ALSDA. The description reflects the original study, while the sample data matches the title.

Option 2: Start class with each group sharing (verbally) their prompt, what their paper was about, and the evidence from the paper that helps explain the assigned question/phrase. Each group should only take a few minutes. Have students access the Visualization portal at: https://visualization.genelab.nasa.gov/data/

1. Filter on the left panel for
   Show only studies with processed data
   Factors: Spaceflight
   Assay Technology Type: rna-sequencing (rna-seq)
2. Apply the filters
3. Scroll through the listing of studies and make a selection
4. Click the "Visualize Study" Button

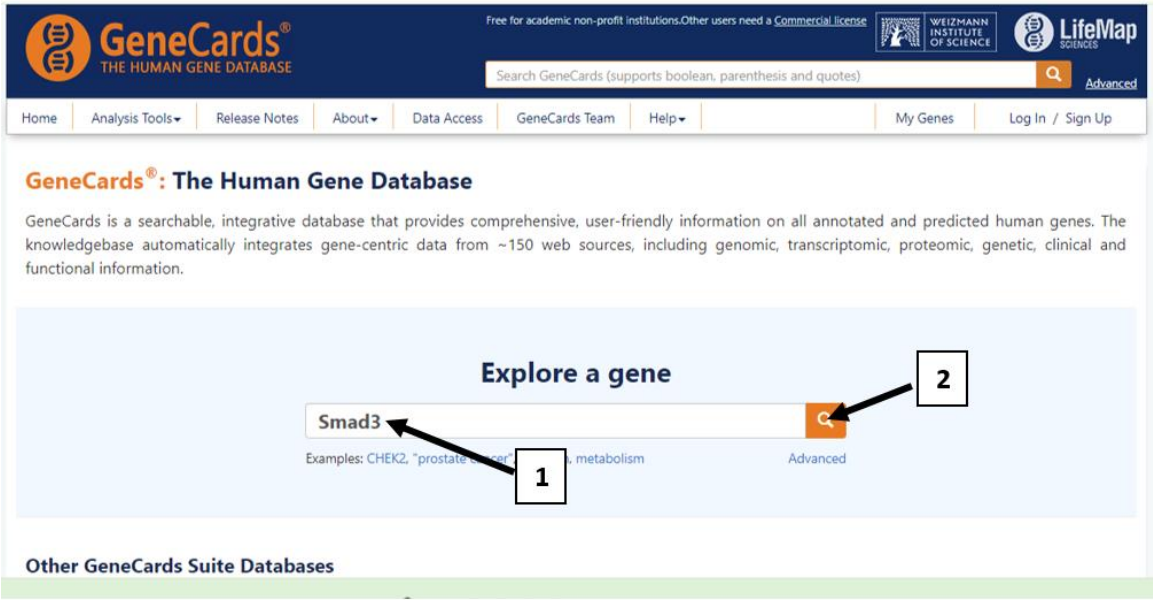


5. Find *volcano plot*
6. Change parameters to
    a. Y-axis: -Log10 (Adj P value)
    b. Adj P val threshold: 0.05
    c. Log_2 FC threshold: 1.5
7. Click *Update*
8. Hover cursor over the 5 highest/furthest blue or red dots to view its gene name. Blue dots represent significantly downregulated genes, red dots represent significantly upregulated genes. Record the 5 most significant differentially expressed (DE) genes.

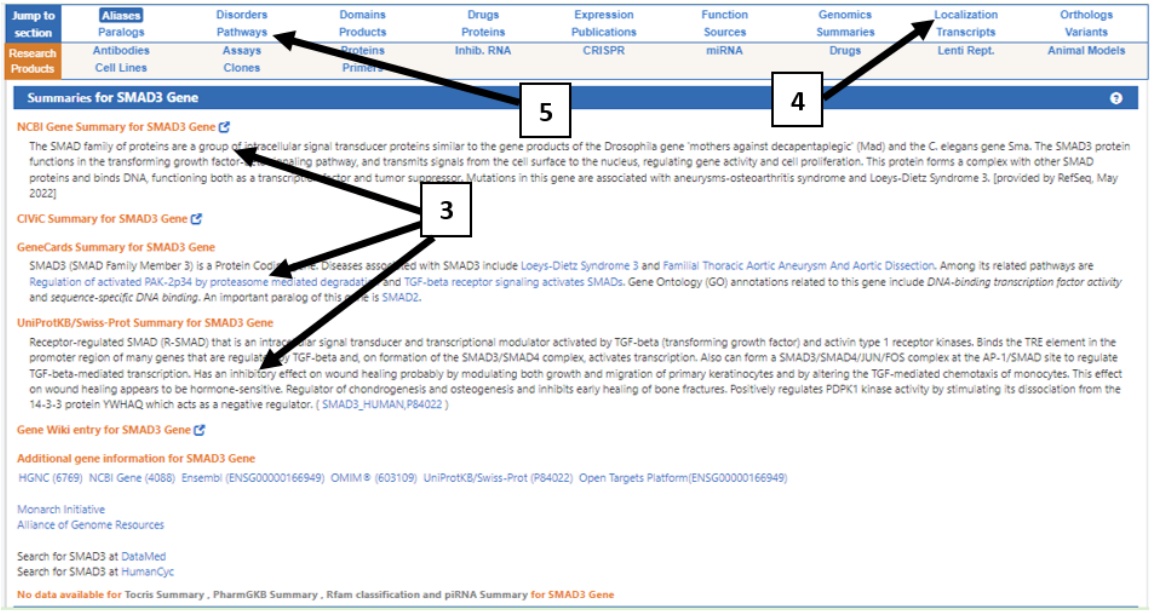


Day 4: Students use genecards.org to explore the functions of the top 10 DE genes.

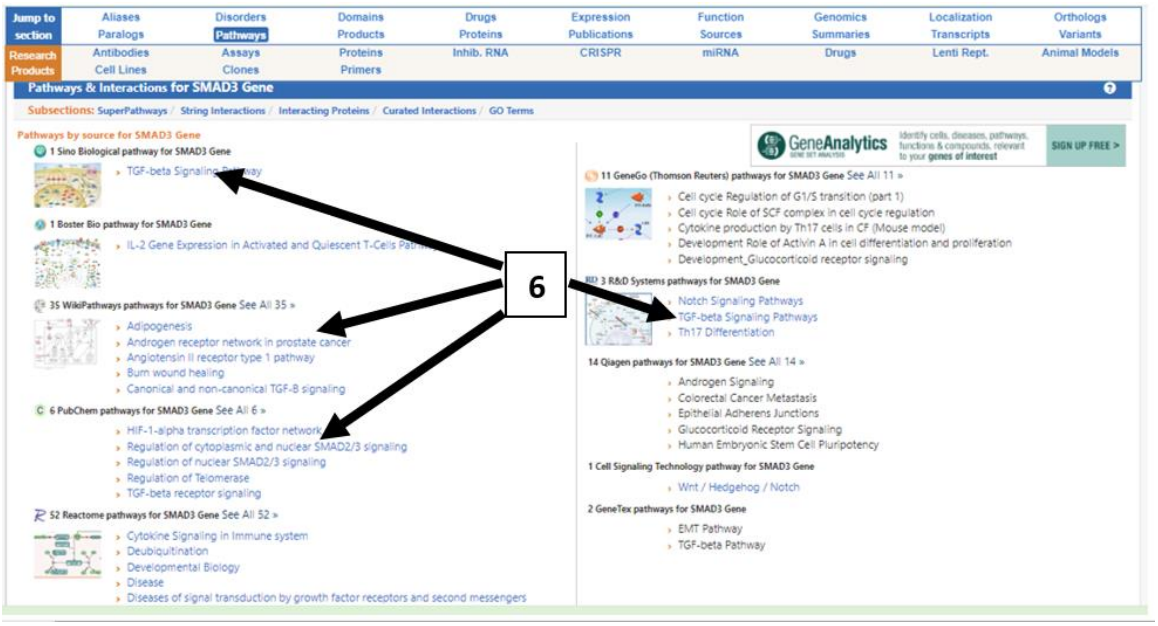
1. Enter the gene name recorded from the volcano plot within the “Explore a gene” search box
2. Click the search button



3. Scroll down and read the summaries for the gene
4. Navigate to “Localization” to learn where in the cell the gene is most located/active
5. Navigate to “Pathways” to learn what role the gene plays in the cell/organism.



6. Read several resources to help formulate an idea of the gene's role and significance. Consider/verify if any of the other recorded DE genes are within the same pathway or have a relationship to the gene.



Based on the genecards.org information, students develop predictions on WHY each of the 5 genes were differentially expressed.

- What does it mean physiologically?
- Can the DE genes help answer the original question?
- If the dataset is not a human study, were the DE genes conserved across organisms?

Day 5: Students present their findings to the class in a short PowerPoint presentation. Students are guided to equally distribute time/labor. PowerPoint slides should be structured as:

Slide 1: Prompt, paper title, student names (2 pts)
Slide 2: About the paper, 5 sentence max. (15 pts)
Slide 3: Volcano plot, only plot and title on page (10 pts)
Slide 4: DE Gene info/relationships, 5 sentence max. (15 pts)
Slide 5: Predictions/Conclusions, 3 sentence max. (10 pts)

*As slides contain few sentences/words, images and other visuals are encouraged!

Additional points for

- Creativity (PPT backgrounds, effects, images, etc.) (5 pts)
- Equal & professional presentation/work distribution (8 pts)
- Ability to answer questions, etc. (5 pts)

70 points total

SAMPLE PRESENTATION RUBRIC

Category	Inadequate	Fair	Good	Excellent	Points Earned
Slide 1: (2 pts) • Prompt • Paper title with author(s) • Team member names • Background • Font variation	**0 pts**: Missing 3+ elements, has no formatting, or slide is missing entirely.	**0.5 pts:** Missing 2 elements.	**1 pt:** missing 1 element but has essential information.	**2 pts:** Has all 5 elements, varied fonts/sizes, and backgrounds are done well.	
Slide 2: (15 pts) • Slide encompasses the main ideas of the paper • Presented in an understandable way • 1+ visual aid • 5 sentences max. • Title/Background	**0 pts:** no slide, or missing 4+ elements.	**5 pts:** Slide missing 2-3 elements.	**10 pts:** Slide is good overall, but is a little confusing, missing 1 element or exceeds sentence max.	**15 pts:** Slide has all elements, is clearly and carefully crafted, and has a valuable visual aid which aids in the paper explanation.	
Slide 3: (10 pts) • Volcano plot generated • Plot labels top 10 DE genes • ONLY title & plot on the slide • Plot is big enough to see • Title/background	**0 pts:** missing plot or slide, slide only has a title, or is missing any 3+ elements.	**5 pts:** Slide has a volcano plot but missing labels, not correctly sized, or missing any 2 elements.	**8 pts:** Slide is missing 1 element, but volcano plot is generated correctly and visible.	**10 pts:** Slide has all elements, is clearly visible, and exceptionally done.	
Slide 4: (15 pts) • All 10 DE genes noted along with their main function/relationship • Visual aid • Title/Background	**0 pts:** missing slide or 3+ elements missing	**5 pts:** missing 2 elements OR all 10 DE genes not addressed OR relationships between genes not addressed.	**10 pts:** missing 1 element but most important elements are well-articulated and shown.	**15 pts:** All DE genes mentioned, relationships between genes/functions are noted, a visual aid to assist presenter in explanation	
Slide 5: (10 pts) • 3 sentence MAX • Predictions plausibly propose WHY a DE gene may be up/down regulated • Visual aid • Title/background	**0 pts:** missing slide or missing 3+ elements	**5 pts:** missing 2 elements or predictions did not address why the change in physiology is occurring	**8 pts:** missing 1 element, but has carefully considered predictions/conclusions	**10 pts:** slide has all elements, predictions/conclusions are well-crafted and	

Creativity: (5 pts) • Entire presentation has • backgrounds beyond a solid color, • varied fonts, • varied visual aids • additional effects (transitions, audio, or other extra features) • NO videos > 10 seconds	**0 pts:** no additional aspects were improved beyond the minimum. Each slide has only a basic/single color background, no variation in text size/font	**1 p** **t:** Notable variation on at least 2/5 slides but missing on others or variation is minimal. Few visual aids.	**3 pts:** Slides have some variation but do not particularly enhance the overall narrative or show anything beyond what is contained in the text.	**5 pts:** Each slide has a background which enhances the presentation but does not impede readability. Title/text fonts and sizes are appropriate and vary as needed. Visual aids demonstrate the main points. Minimum of 1 visual per slide OR additional effect that enhances the presentation.	
Presentation Distribution: (8 pts) • Students equally participate in presentation • Students equally participate in research, preparation, slide/content creation	**0 pts:** ALL students do not completely meet either element.	**3 pts:** ALL students meet at least 1 element	**6 pts:** ALL students meet at least 1 element AND most students meet the 2nd element.	**8 pts:** BOTH elements are met by ALL students	
Knowledgeable: (5 pts) • Students seem knowledgeable about the information/paper • Students can answer questions with relative reliability or propose possible answers	**0 pts**: Students cannot answer questions and do not seem familiar with their paper	**1 pt:** Students are familiar with their paper but cannot answer questions	3 pt**s:** MOST students are familiar with paper and can answer basic questions	**5 pts:** ALL students are well-versed on all aspects of the presentation, can converse on the main topics of the scientific article, and are knowledgeable enough to propose possible answers to questions they do not know the answer to.	
				TOTAL	

REFERENCES TO DATA SETS

Datasets will be retrieved from the Open Science Data Repository. Datasets used for this lesson will be filtered for transcriptomics studies and for those that have GeneLab Processed Data available. At the time of submission, the datasets suggested for use in this lesson are: OSD-580, OSD-247, OSD-373, OSD-457, OSD-244, OSD-588, OSD-207, OSD-254, OSD-162, OSD-664, OSD-467.

Links to Student Versions of Counts Files for Datasets:

OSD-580: https://usegalaxy.org/u/bgrissom/h/osd-580
OSD-247: https://usegalaxy.org/u/bgrissom/h/osd-247
OSD-373: https://usegalaxy.org/u/bgrissom/h/osd-373
OSD-457: https://usegalaxy.org/u/bgrissom/h/osd-457-liver
OSD-244: https://usegalaxy.org/u/bgrissom/h/osd-244
OSD-588: https://usegalaxy.org/u/bgrissom/h/osd-588
OSD-207: https://usegalaxy.org/u/bgrissom/h/osd-207
OSD-254: https://usegalaxy.org/u/bgrissom/h/osd-254
OSD-162: https://usegalaxy.org/u/bgrissom/h/osd-162
OSD-664: phenotypic data only
OSD-467: Data processing request submitted; document will be updated upon completion.

STANDARDS ALIGNMENT

NGSS Standards
Strands: HS-ETS1-3, HS-ESS3-4, HS-LS1-3
Practices: Analyzing and Interpreting Data; Using Mathematics and Computational Thinking. Construction Explanations and Designing Solutions
Crosscutting Concepts: Interdependence of Science, Engineering, and Technology; Influence of Engineering, Technology, and Science on Society and the Natural World

Strands: HS-LS1-2; HS-LS1-3; HS-LS4-1
Practices: Developing and Using Models; Asking Questions and Defining Problems; Analyzing and Interpreting Data
Crosscutting Concepts: Interdependence of Science, Engineering, and Technology; Influence of Engineering, Technology, and Science on Society and the Natural World

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