FUTURELAB+

AG/ENVIRONMENTAL

Solution Seeking Microbes

Microbes and Balance in the Environment

Developed in partnership with:
Discovery Education and Ignited

In this Lesson Plan:

Print the **Teacher Section** →

Print the **Student Section** →

This document is separated into two sections, For Teachers [T] *and* Student Resources [S], *which can be printed independently.*

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Cover Image
Lactobacillus casei is one of many friendly bacteria in your gut microbiome.

AG/ENVIRONMENTAL / SOLUTION SEEKING MICROBES

Microbes and Balance in the Environment

ACTIVITY DURATION

Four class sessions
(45 minutes each)

DRIVING QUESTION

How can we engineer microbes to convert waste products into something useful?

ESSENTIAL QUESTIONS

How do greenhouse gases, such as CO_2 play a role in climate change?

How can microbes be used to reduce waste produced in industry by converting these wastes into less harmful or even useful products?

OVERVIEW

Although atmospheric carbon dioxide levels fluctuate over time, in the last millenium levels have not been anywhere near what they are today. Advancing human technologies have had a clear impact on the amount of greenhouse gases in our atmosphere, resulting in global temperature rise, warming oceans, shrinking ice sheets, glacial retreat, decreased snow cover, sea level rise, declining Arctic ice, ocean acidification, and extreme weather events. Although some people may have the resources to remain unaffected by these changes, there are many who do not. We need to continue to develop technologies to combat the changes made by our industrial society.

Students will review greenhouse gases, specifically carbon dioxide (CO_2) emissions, and their effects on climate in order to understand the problem and the urgency to address it. Once students have grasped the importance of dealing with these emissions, they will explore the emissions' sources, focusing primarily on industry. Students will analyze a case study modeled after a United States based company that is using engineered microbes to convert CO_2 emissions from a steel mill into useful products, such as biofuel.

OBJECTIVES

Students will be able to:

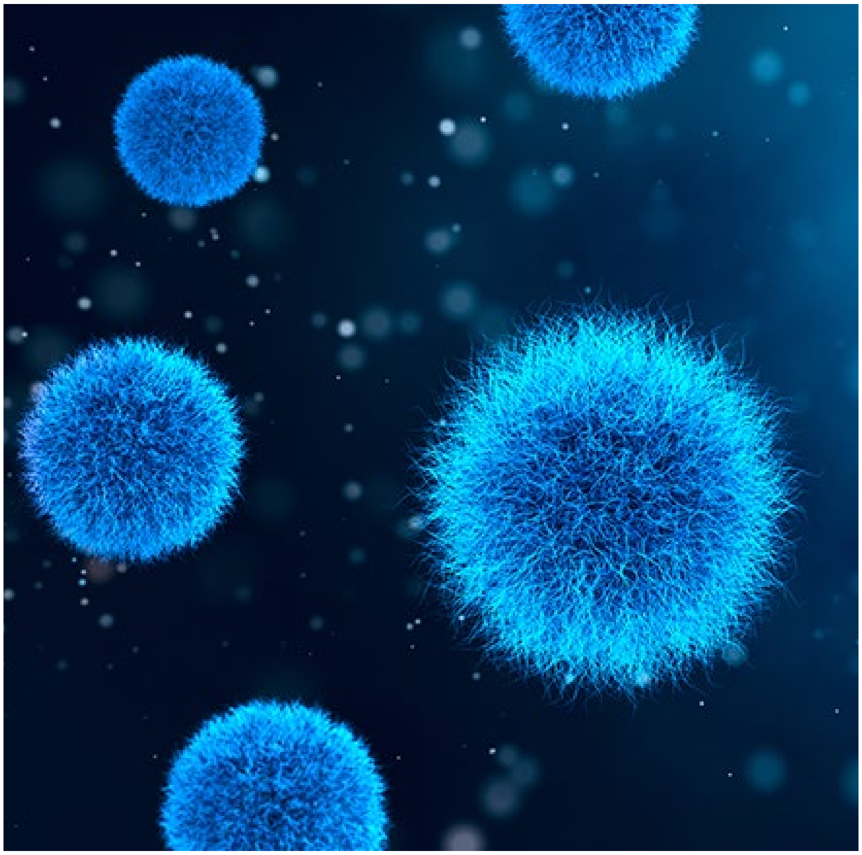
Identify the connection between greenhouse gas levels (CO_2) and climate.

Analyze sources of CO_2 emission and prioritize sources that need to be addressed.

Explain how microbes can be engineered to transform waste products.

BACKGROUND INFORMATION

The following resource explains the significance of the world passing a carbon threshold, *How the World Passes a Carbon Threshold and Why it Matters*.



This image shows a 3D rendering of a microbe.

Materials

- **CO_2 Data Extrapolation Capture Sheet**
- **Climate Change Simulation Capture Sheet**
- **Using Microbes for CO_2 Emissions Reading**
- **Greenhouse Gas Emissions from Large Facilities Capture Sheet**
- **Microbes to the Rescue Capture Sheet**
- **Career Profile: Ryan Tappel, PhD**
- **Toolkit**

Pedagogical Framing

Instructional materials are designed to meet national education and industry standards to focus on in-demand skills needed across the full product development life cycle—from molecule to medicine—which will also expose students and educators to the breadth of education and career pathways across biotechnology.

Through this collection, educators are equipped with strategies to engage students from diverse racial, ethnic, and cultural groups, providing them with quality, equitable, and liberating educational experiences that validate and affirm student identity.

Units are designed to be problem-based and focus on workforce skill development to empower students with the knowledge and tools to be the change in reducing health disparities in communities.

SOCIAL-EMOTIONAL LEARNING

Students will demonstrate responsible decision making as they evaluate the benefits and consequences of greenhouse gas emissions, and their inequitable impact on various members of the community. Students will also exhibit self-management of their emotions as they will undoubtedly feel inspired to act as they observe local facility emissions, however they will be reminded to stay respectful and try to inspire improvements rather than targeting these facilities.

CULTURALLY AND LINGUISTICALLY RESPONSIVE INSTRUCTION

Students will address real-world issues while they ideate how to inspire local companies to utilize microbes to reduce emissions, which affect community members with fewer resources to adapt to changing climate more than others.

ADVANCING INCLUSIVE RESEARCH

In this lesson, students will analyze greenhouse gas emissions from around the world to make connections to the geographical distribution of environmentally disadvantaged communities. They will uncover disparities (race, income level, age) that impact how different communities, in this country and around the world, will be impacted by climate change. They will examine how industry can collaborate with local communities to promote environmentally friendly technologies that will not harm disadvantaged areas.

COMPUTATIONAL THINKING PRACTICES

In this lesson, students use the computational thinking strategies of analyzing data and finding patterns to make predictions about how the climate will continue to change. By using these strategies, students are able to understand how mitigating factors, such as microbes, can make a difference in rising CO_2 levels.

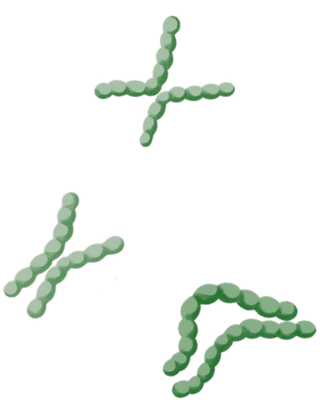
CONNECTION TO THE PRODUCT LIFE CYCLE

In this lesson students learn about how new technologies utilizing microbes are being implemented in facilities to reduce CO_2 emissions and identifying local facilities with high emissions to hypothetically persuade them to incorporate these technologies. This relates to the **commercialize** phase of the product life cycle as new technologies are incorporated throughout the world.

Have you ever wondered…

How have microbes been used to enhance or remediate the environment?

As humans continue to emit CO_2 into the atmosphere from a variety of sources, we need to develop new technologies to counter these emissions. Microbes have been shown to adapt and actually thrive in harsh environments, utilizing their surroundings to create energy. Some facilities have begun implementing microbial technology as a way to reduce emissions. If we can communicate the benefit of this technology to more companies, we may be able to have a dramatic impact on emissions. The effects of climate change impact everyone, however certain groups of people who have fewer resources to accommodate these global changes will be impacted even more.



MAKE CONNECTIONS!

How does this connect to the larger unit storyline?

One of the possible main topics students will be addressing in their final project is using microbes to positively impact the environment. In this lesson, students will be learning how microbes are currently being used to reduce pollution and emissions. The main goal is for students to understand that microbes can be modified to complete the reactions that will transform something harmful to the environment into something less harmful, reducing human impact.

How does this connect to our world?

This lesson will focus on a case study built around a real company that is currently using microbes to solve an environmental problem.

How does this connect to careers?

Environmental scientists conduct field and lab research around how to protect and improve human health and the health of our environment. They design research studies, review existing literature, and advocate for changes in their communities and our planet overall based on their work.

Sustainability engineers work to solve problems with minimal materials in order to reduce resource use and promote a healthy planet for future generations. They might use metrics, such as socioeconomic and health indicators for humans from the United Nations (U.N.), or environmental indicators, such as biodiversity and carbon emissions for the planet, to measure the success of their solutions in promoting health and balance.

Bioprocess engineers or ***biochemical engineers*** work to optimize production or optimize waste breakdown of food, pharmaceuticals, polymers, and other products. They often conduct lab and field tests with scaled bioreactors to improve a process, and their results inform how companies manufacture goods or how municipalities handle wastes at a larger scale.

Day 1

LEARNING OUTCOMES

Students will be able to:

Make predictions about future climate data based on current trends.

This is an image of the Mauna Loa Observatory on top of Mauna Loa in Hawai'i.

Procedure

Small Group (7 minutes)	
1	Ask students if they know what CO_2 is or where it comes from. Ask students what they have heard about CO_2 in the atmosphere. Pose questions such as: *How much of the atmosphere is comprised of CO_2? Is the amount increasing, decreasing, or staying the same? Why? What impact do these changes have on people and the places where they live?* Tell students that it is ok to not know much about this yet. Explain that they will be exploring changes in atmospheric CO_2, climate change, and ways to mitigate damages caused by human emissions, and of course, ways that microbes will play a role!
2	Think/Pair/Share: Ask student pairs to discuss why they think climate change is an issue and why we need to address it. Allow students to share their thoughts with the whole class. Point out to students that living things can adapt to slow changes over time, but that it is the fast rate of change that is concerning. You may wish to show students the thought experiment outlined at *Why Should We Care About Climate Change*.
3	Think/Pair/Share: Ask student pairs to discuss with each other: *If you were to collect data regarding atmospheric CO_2 levels, where would you keep your data probe so that it is consistent and truly getting readings of global atmospheric CO_2 levels?* Ask student pairs to share their ideas and why they chose those places.
4	Tell students that scientists brainstorm too! After thinking about this same question, scientists chose to place the data probe at the Mauna Loa Observatory in Hawaii. According to NOAA (National Oceanic and Atmospheric Administration), because the observatory is located on an island in the middle of the Pacific Ocean away from major air pollution sources and high enough above the local population, it is a good choice for monitoring global CO_2 levels.
5	Go to the live camera on *Mauna Loa Observatory* to show students what it looks like on any given day. Tell students that scientists only started collecting CO_2 data in 1958. Explain that you will look at this data from 1960–1980 and make predictions about the changes in CO_2 over the years. Later in this lesson, students will project what they think it will look like with the interventions many groups are making around the world.

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Day 1

Continued

Procedure

Whole Group (30 minutes)	
1	Show students the graph on the *CO_2 Data Extrapolation Capture Sheet* to explain the axes. This graph has data filled out until 1980. Explain the axes (the concentration of CO_2 in the atmosphere, measured in parts per million, by year). Tell students that the Mauna Loa Observatory long-term CO_2 monitoring program has been running since 1958. The red lines and symbols represent the monthly mean values, centered on the middle of each month. The black lines and symbols represent the same, after correction for the average seasonal cycle. Point out that this is why the red lines are vacillating up and down over the black line. Ask students why they think CO_2 levels would vacillate by seasons (you may further probe them if they have a hard time by discussing when photosynthesis might be occurring more or less during the year).
2	Hand out the *CO_2 Data Extrapolation Capture Sheet* to each student. Show the first graph in *Educator Resources: Atmospheric CO_2 at Mauna Loa Observatory, 1960–1980* and ask students to draw the data they see. Students should then extrapolate the data to 2000. Tell students that when they predict values for points outside the range of data taken it is called extrapolation. When they predict values within given data points, it is called interpolation.
3	Now, show the second graph found in *Educator Resources: Atmospheric CO_2 at Mauna Loa Observatory, 1960–2000*. Ask students to draw the data they see on that graph and compare it to their extrapolation. Were their predictions accurate?
4	Ask students to extrapolate to 2018 from the 1960–2000 data on their capture sheet.
5	Now show the final graph found in *Educator Resources: Atmospheric CO_2 at Mauna Loa Observatory, 1960–2018*. Ask students to repeat their comparison.
6	Ask students to make a future trajectory to 2040.
7	Discuss how consistent and clear the overall curve is (the black line is the average). Most scientific data does not show such a clear trend.

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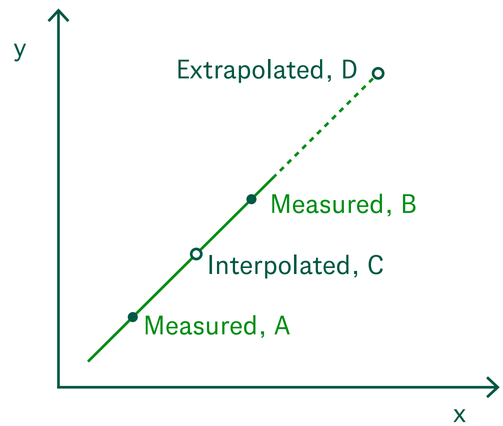
Day 1

Continued

Procedure

8 Notice the actual data seems to follow an annual cyclical pattern (the red line). Discuss what the factors might be driving the yearly ups and downs. [More information on seasonal factors affecting atmospheric CO_2 can be found on the NOAA website.]

9 Discuss how extrapolation and interpolation are different, and why interpolation is impossible for making predictions. (Extrapolation: estimating or concluding something by assuming that existing trends will continue; interpolation: estimating unknown values that fall between known values.)



10 Direct students to the *EnRoads* website. Ask students to view the graph on the right, which extrapolates all emissions through 2100. Ask: *If we continue to extrapolate, what will happen to the global temperature by 2100?*

11 The Paris Agreement is an international, legally-binding treaty on climate change that aims to limit global temperature increase to 1.5°C by 2050. You may wish to share a graphic from the World Wildlife Fund on *Climate Risks: 1.5°C Vs 2°C Global Warming* with students to help them understand why this is important. Tell students to change the graph on the left so they are looking only at CO_2 emission data (under impacts). Tell them to manipulate the bars at the bottom of the screen, choosing various ways in which this might be accomplished. They should take a screenshot of their findings and place it in their *CO_2 Data Extrapolation Capture Sheet*.

Extension Activity

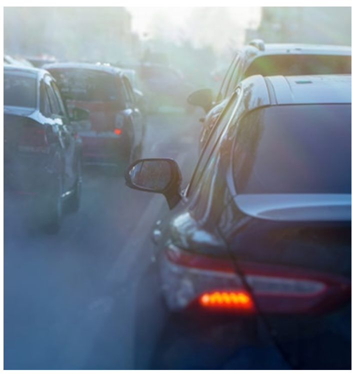
You may wish to discuss the various target *trajectories* of the *Paris Agreement*, and what factors are involved in meeting different goals.

Day 2

LEARNING OUTCOMES

Students will be able to:

Analyze data to determine the effect of CO_2 concentration on global temperature.



Procedure

Whole Group (15 minutes)	
1	Ask students to review the data trends they observed yesterday with a partner. Ask students if they know what effects CO_2 has on our planet. Remind students that CO_2 emissions have been increasing. Record responses on the board. After students finish explaining their ideas, tell them that today they will use a simulation to investigate how CO_2 affects climate.
2	Hand out the *Climate Change Simulation Capture Sheet* and direct students to the *NetLogo Web* virtual lab.
3	Tell students to set the parameters listed on their capture sheets and watch a ray of sun as it enters Earth's atmosphere. Tell students to discuss questions a–e with their partners.
4	When students have finished, discuss the answers with the class. Encourage students to ask more questions based on the simulation.

Small Group (30 minutes)	
1	Review the components of the simulation with students. Tell them to record global temperature data every 500 ticks with no clouds and no CO_2 for the first simulation, 10 clouds and no CO_2 for the second simulation, and no clouds and 300 CO_2 for the third simulation. Remind students why it is important to change only one variable at a time (so they can isolate the variable that is having the effect).
2	Tell students to graph their data and calculate the rate, using the slope of the line, for each trial. Ask students which of the scenarios had the greatest rate of increase. If students have trouble calculating the slope of a line, you may wish to review this calculation beforehand. If using a digital program to graph, you may wish to tell students to add a line of best fit and label with the equation that will contain the slope.
3	Tell students to work with their partners to answer the conclusion questions. They should create a claim answering the question: *What are the factors that affect climate change and how does each affect solar rays?*

Day 3

LEARNING OUTCOMES

Students will be able to:

Research and **identify** local sources of CO_2 emissions.

Explain how microbes can be utilized to reduce CO_2.

This is an image of a colorful geothermal basin in Yellowstone National Park, Wyoming.

Procedure

Small Group (45 minutes)	
1	Ask students: *What do microbes eat?* Remind students that there are extremophiles that live in conditions living things would normally not occupy, however these bacteria thrive, even without light and the normal source of energy. Tell students that if bacteria are able to thrive in these conditions and use alternative chemicals for energy, maybe we can use their ability to adapt and evolve to combat rising CO_2 emissions!
2	Have students read the *Using Microbes for CO_2 Emissions Reading* article and answer the questions on the *Greenhouse Gas Emissions From Large Facilities Capture Sheet* with their partners.
3	Review the answers with the class after five to ten minutes, asking students to volunteer their answers.
4	Remind students that CO_2 has a direct impact on our global climate. Ask students the following question: *Where do you think this CO_2 is coming from?* Look back at the En-Roads activity if you need a hint. Record what students say on the board as a list.
5	Most of the student responses will most likely be broad categories. If there are no local examples, ask students if they know of any facilities or sources of CO_2 in their area. Add these to the list.
6	Tell students that they will be investigating their local CO_2 emissions and finding areas of interest that would be good candidates for microbial CO_2 emissions reduction technology.
7	Have students go to the following website: *Welcome To The Green House Gases Mobile Website*.
8	Tell students to follow the directions in their *Greenhouse Gas Emissions From Large Facilities Capture Sheet* to find county CO_2 emissions sources. Remind students that they will observe local companies, emissions by sector, and trends over time. Tell students that ultimately they will further research one facility from their local area or an area of their choice to identify the processes occurring at this facility, how this facility benefits their community (e.g., economically), and harms their community (e.g., environmentally), and decide if these benefits are equitable.

Day 4

Procedure

LEARNING OUTCOMES

Students will be able to:

Explain benefits of microbial technology as a method to reduce emissions.

Identify the inequitable impacts of climate change on people in their community.

Whole Group (5 mins)

Remind students that yesterday they identified a local facility that produces high CO_2 emissions. Ask student groups to share with the class which facilities they came up with, making a list on the board. If a student group finds a particular one more interesting or important and relevant to them, tell them they may wish to change their focus.

Small Group (10 mins)

1 After students have selected the facility of interest, tell them that they will try to convince this company to implement microbial technology to help reduce CO_2 emissions. Tell students that they need evidence of the success of this technology to gain the trust of this company. Pass out the *Microbes to the Rescue Capture Sheet*. Give students time to read *Capturing Carbon's Potential: These Companies Are Turning CO_2 into Profits* from Columbia Climate School to identify at least four companies and explain how they have benefited from the use of microbes.

2 Review the benefits of using microbes with the class, reminding them that each benefit is a way for them to try to convince the facility they have identified to use microbial technology.

Whole Group (5 mins)

Remind students that the impacts of climate change include the following: global temperature rise, warming oceans, shrinking ice sheets, glacial retreat, decreased snow cover, sea level rise, declining Arctic ice, ocean acidification, spread of disease vectors, and extreme events. Ask students if they think everyone is equally affected by these events, and allow students to share their thoughts.

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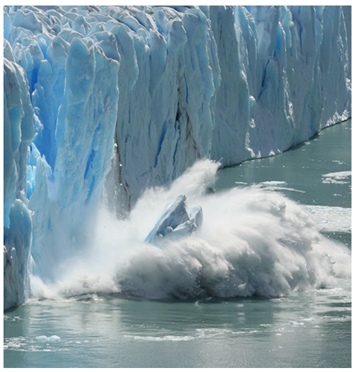
Day 4

Continued

Procedure



Small Group (25 mins)	
1	Have students read *Climate Impacts on Society* from the EPA and give specific examples of vulnerable populations and the hardships these people face. Review briefly if students have questions.
2	Tell students that they will help share awareness about the impact of climate change on vulnerable populations and solutions to reducing CO_2 emissions by creating a way to socially communicate to their community members and/or the specific facility. Students may wish to make an Instagram/Facebook/Snapchat/Tiktok/email or other. Remind students that they are trying to work together with the community and industry, that they are not trying to get a facility shut down or create negative reviews, but rather promote environmentally friendly technology.
3	Invite students to answer the Lesson 8 questions in the **Toolkit**. Give students an opportunity to read the scientist profile on *Ryan Tappel*, focusing on what he does in his field and what might be most relatable or what resonates most with the students. They should log their thoughts in the **Toolkit**: *Based on the career profile in this lesson, what does this tell you about the types of people that do science? What did you find most relatable?* If time permits, you may ask students to share their thoughts.

Optional Extension Activity

As an optional extension, students can read *Green Genes*, an article about how Genentech put some environmental practices in place or articles illustrating more ways that microbes have been used in environmental enhancement and remediation, such as *Coty to Partner with Lanzatech to Pioneer New Sustainable Fragrance Production*, *Bioremediation and Biosensing Using Bacteria*, *Application of Microbial Cleaning Technology for Removal of Surface Contamination*, and *Microbes turn Carbon Dioxide into Methane*.

National Standards

Next Generation Science Standards

LS2-7 Ecosystems: Interactions, Energy, and Dynamics
Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

LS4-6 Biological Evolution: Unit and Diversity
Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.

Science and Engineering Practices
Constructing Explanations and Designing Solutions
Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade off considerations.

Analyzing and interpreting data
Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

Crosscutting Concepts
Cause and Effect
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Stability and Change
Much of science deals with constructing explanations of how things change and how they remain stable.

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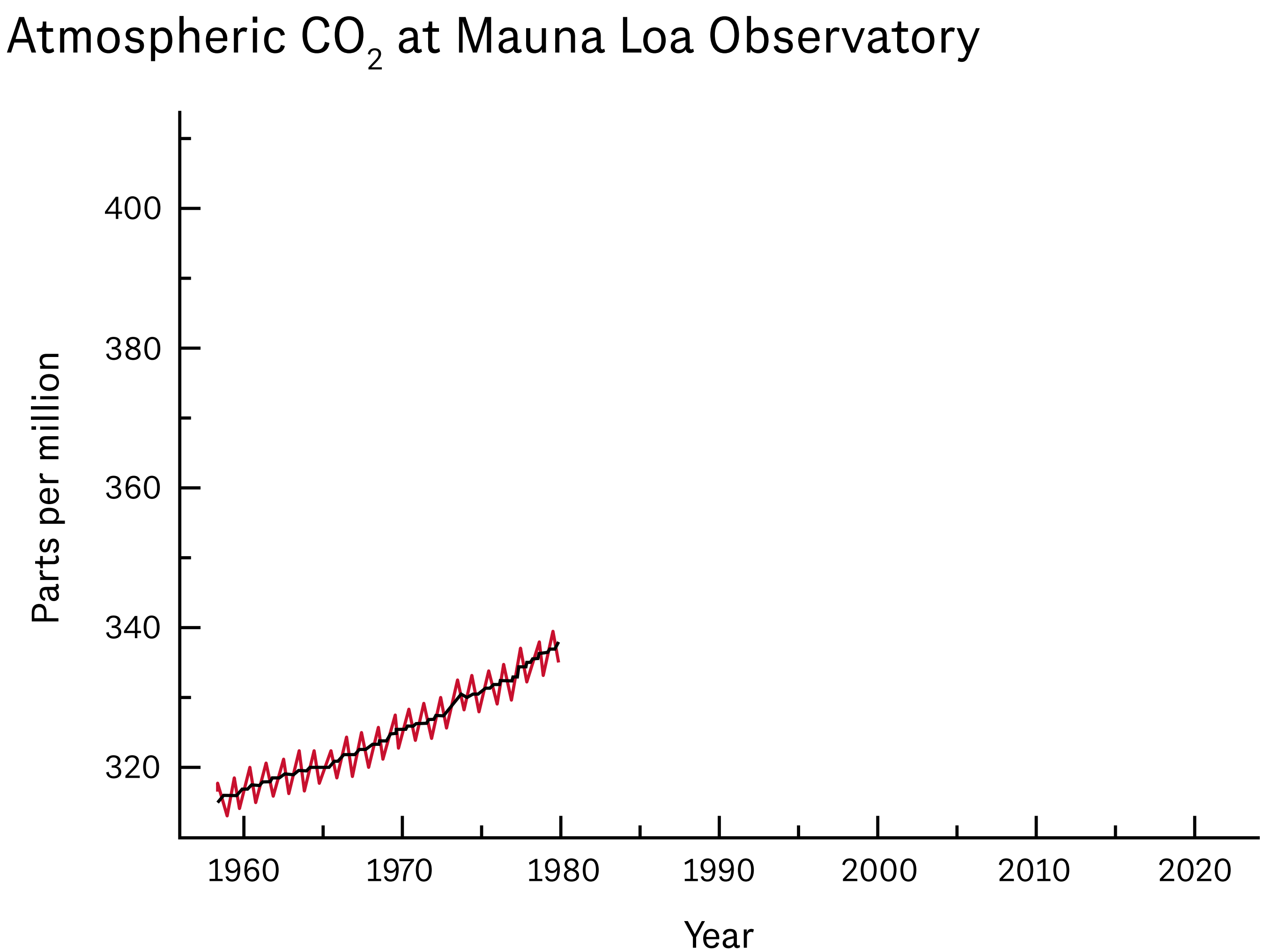
National Standards

Career and Technical Education (CTE) *Continued*	**A1.3** Recognize the role of innovation in creation of emerging biotechnology careers, including those in nanotechnology, biofuels, and forensics.
	2.4 Demonstrate elements of written and electronic communication such as accurate spelling, grammar, and format.
	4.1 Use electronic reference materials to gather information and produce products and services.
	4.3 Use information and communication technologies to synthesize, summarize, compare, and contrast information from multiple sources.
	4.5 Research past, present, and projected technological advances as they impact a particular pathway.
	5.6 Read, interpret, and extract information from documents.
	7.4 Practice time management and efficiency to fulfill responsibilities.
	7.8 Explore issues of global significance and document the impact on the Health Science and Medical Technology sector.

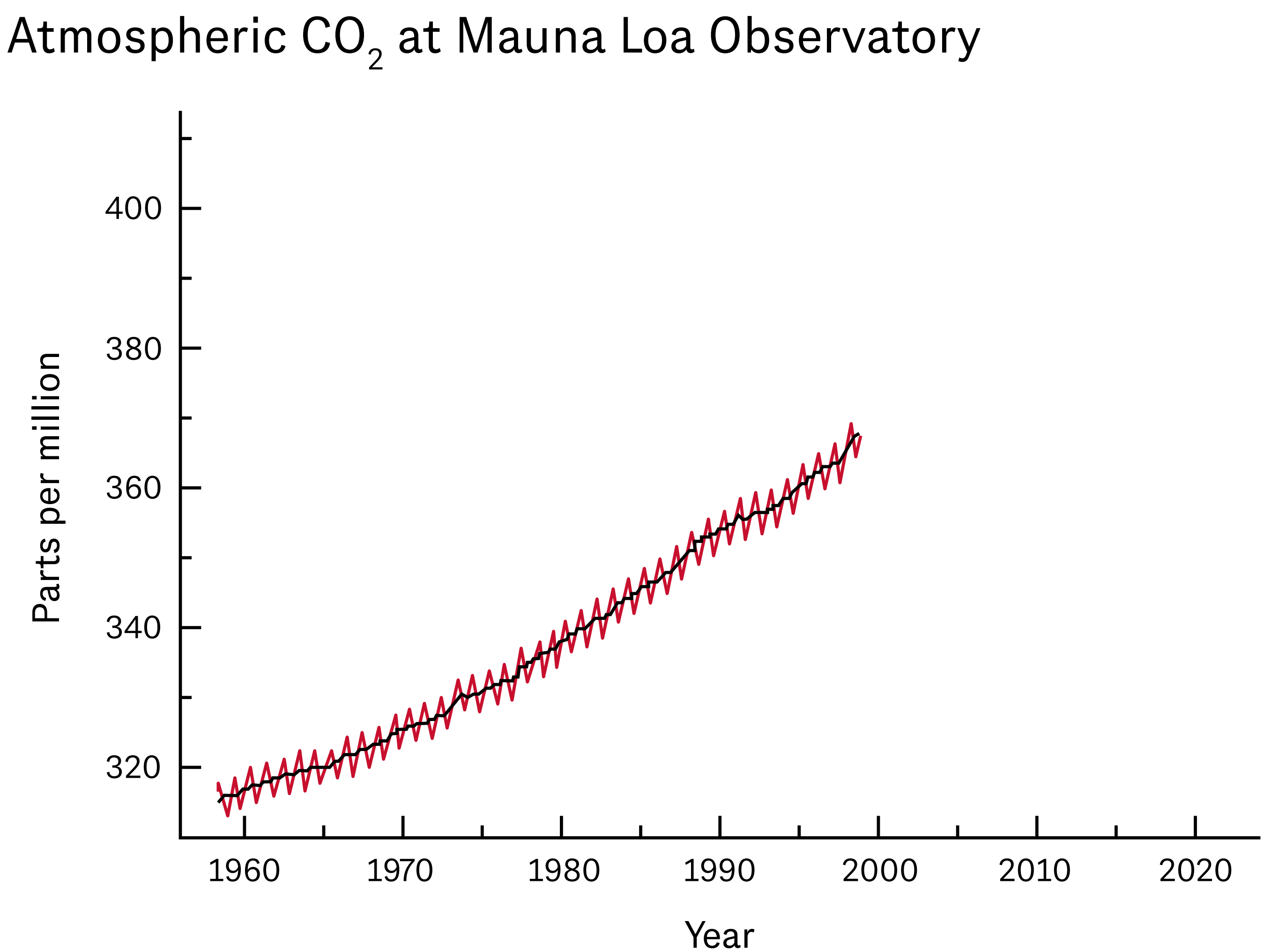
Educator Resources

Atmospheric CO_2 at Mauna Loa Observatory, 1960–1980



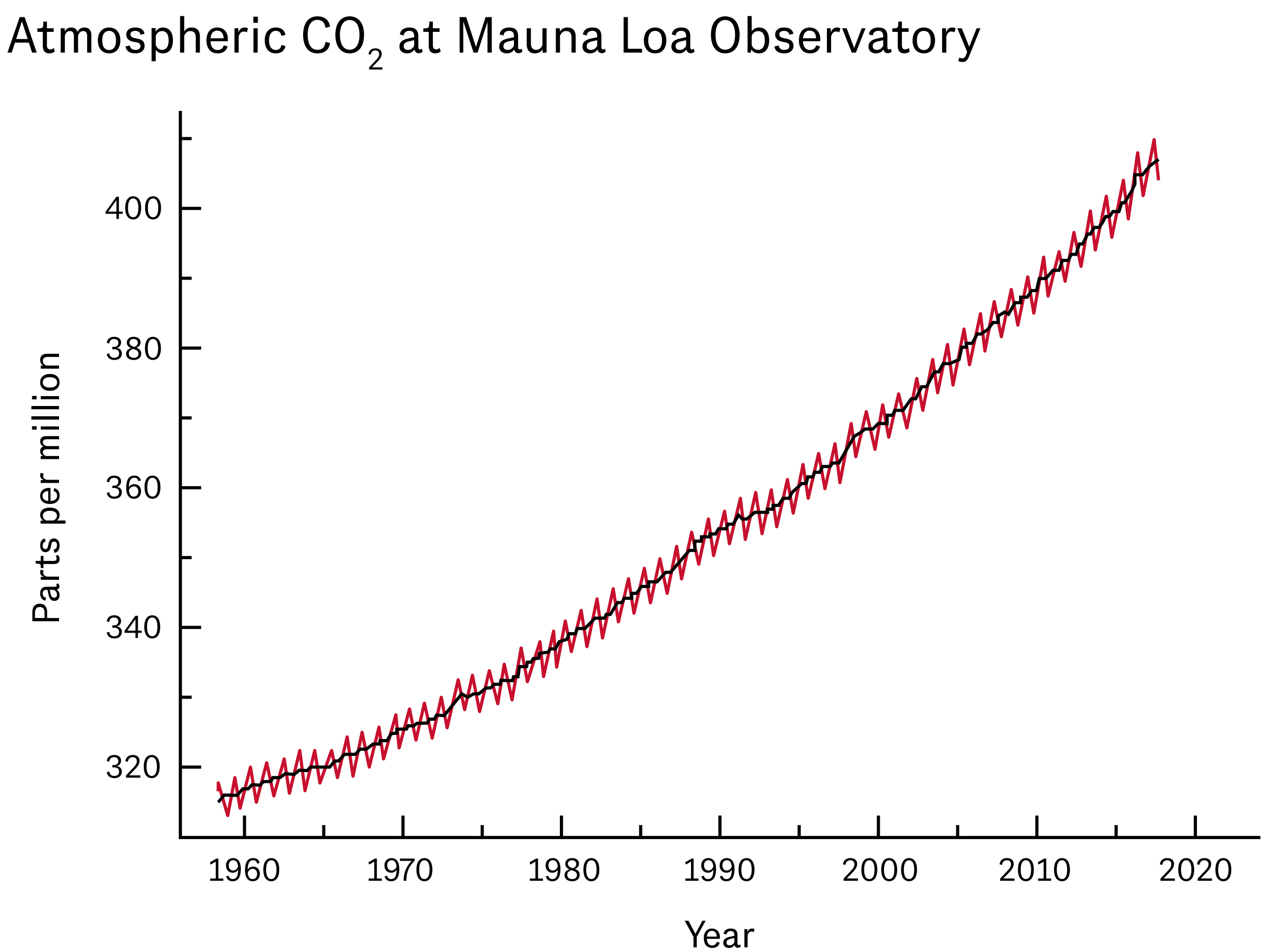
Educator Resources

Atmospheric CO_2 at Mauna Loa Observatory, 1960–2000



Educator Resources

Atmospheric CO_2 at Mauna Loa Observatory, 1960–2018



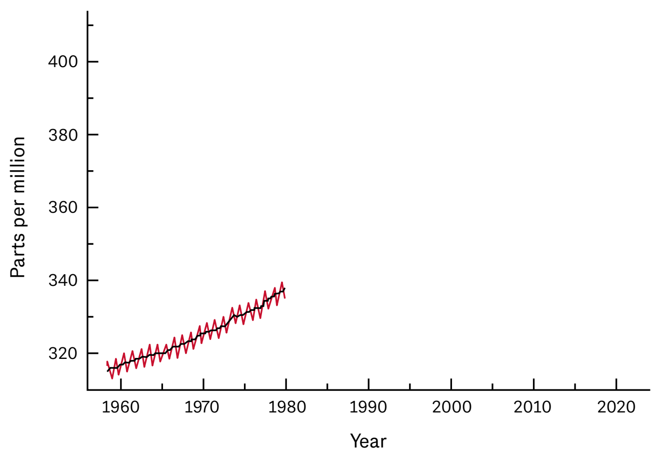
CO_2 Data Extrapolation Capture Sheet

ANSWER KEY **Do not share with students**

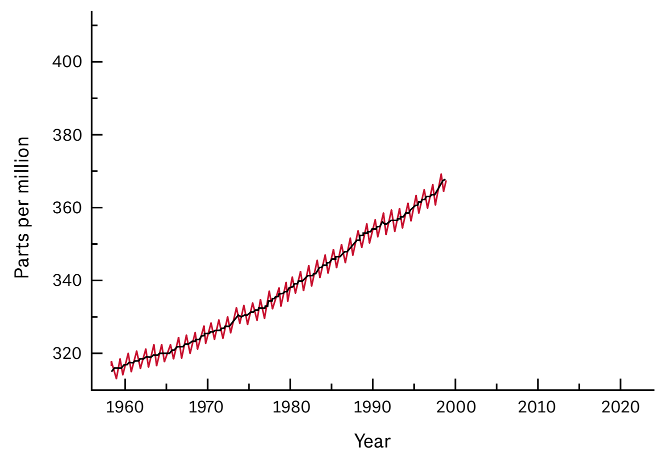
Directions

Show students the following graphs to reproduce on their graphs in stages (first show the data only until 1980, then to 2000, then to 2018).

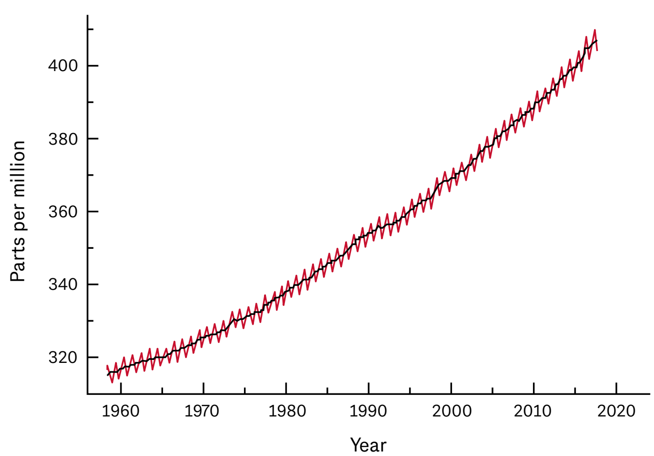
Atmospheric CO_2 at Mauna Loa Observatory



Atmospheric CO_2 at Mauna Loa Observatory



Atmospheric CO_2 at Mauna Loa Observatory



1. Identify the axes in the graph above.

x-axis: year
y-axis: parts per million

2. What are the units used to measure CO_2?

parts per million

3. What does this unit mean?

It means the absolute fractional amount that CO_2 is measured in multiplied by 1 million.

4. Replicate the data from 1960-1980 provided by your teacher in your graph.

5. Draw a line predicting what the data may look like from 1980–2000.

6. Replicate the data from 1960-2000 provided by your teacher in your graph.

7. How did your prediction compare to the actual data? How does this make you feel?

Example: My prediction was an underestimate compared to the actual data. This makes me feel nervous because it indicates that global warming is happening at a faster rate than I thought.

8. Now make a final prediction. Draw a line to illustrate what you think the data from 2000–2018 will look like.

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CO_2 Data Extrapolation Capture Sheet

ANSWER KEY **Do not share with students**

Continued

9. Replicate the data from 1960-2020 provided by your teacher in your graph.

10. How did your prediction compare to the actual data? How does this make you feel?

Example: This prediction was also an underestimate. The actual data seems to indicate that CO_2 in the atmosphere is rising exponentially, which is really fast. This also makes me nervous because it means global warming is happening way faster than I thought.

11. Do you think the graph illustrates consistent data? Explain with evidence.

The graph does illustrate consistent data. Although the atmospheric CO_2 increases and decreases a consistent amount of times each decade (indicated by the red line), the overall ppm is increasing exponentially, as can be seen by the trend line.

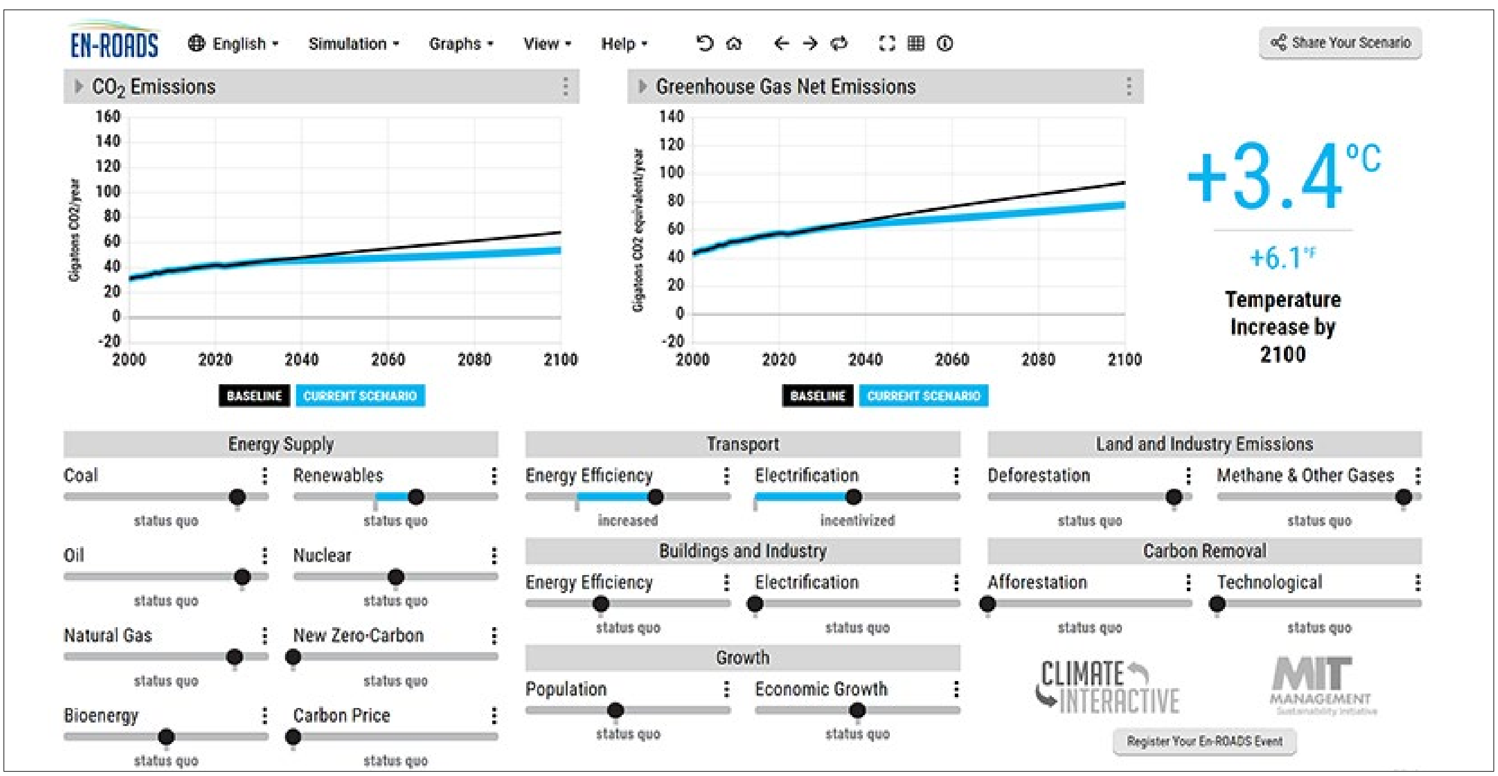
12. What is a pattern you can observe in the graph? Why do you think this pattern exists?

A pattern I can observe by the graph is that the CO_2 levels increase and decrease consistently. This is likely seasonal. I think that plants in the spring and summer sequester more carbon than they do in the fall and spring, leading to a rise of atmospheric CO_2 in one season and a fall in the other.

13. Go to the *En-Roads* website. Looking at the graph on the right, to what are emissions linked?

They are linked to factors, such as energy supply, transport, buildings and electricity, growth, land and industry emissions, and carbon removal.

14. Change the graph on the left on En-Roads so you are looking only at CO_2 emissions. Screenshot your En-Roads simulation, showing what you chose to manipulate to get the global temperature down by 1.5˚C by 2050.



Climate Change Simulation Capture Sheet

ANSWER KEY **Do not share with students**

Virtual Lab
Go to the following website: *NetLogo Web*.

We will investigate how solar energy interacts with Earth systems and the factors that affect climate change.

Procedure

1. Open the virtual lab.
2. Set the following parameters:
    - Click "Set-up."
    - Set sun-brightness to 1.0.
    - Set albedo (how much light is reflected by the surface) to 0.50.
    - Click the "add cloud" button four times.
    - Click the "add CO_2" button four times.

3. Click "Go." Click the "Watch a ray button" and see what happens to the sun's rays to answer the following questions. You may need to watch multiple rays to answer all the questions.

    a. What are the possible outcomes as the rays hit the ground?

It could bounce back up and go up to the sky.

It could bounce back up and bounce off a cloud back onto the ground.

It could penetrate the ground and go into it, bouncing back up against the surface of the ground.

It could bounce back up and pass through a cloud.

    b. How do the rays interact with the clouds?

The rays bounce off the clouds, but occasionally pass through them.

    c. What happens to the rays that have entered the ground?

They attach to a particle and stay trapped underground.

    d. Set the "albedo" to 1.00. What happens now as the sunlight hits the ground?

All the rays bounce off the ground, so there are none that enter the ground.

    e. Where on Earth would be similar to an albedo of 0.50? Where would be similar to an albedo of 1.00?

Colder places, such as the North and South poles, would likely be similar to an albedo of 1.0. Hotter places near the equator would likely be similar to an albedo of 0.5.

4. Reset the simulation with no clouds and no CO_2 keeping the albedo set at 0.5. Click "Set up" and "Go".

5. Allow the simulation to run until you get to 500 ticks, and then pause the simulation to record the global temperature in the following data table. When finished recording data, resume. Run the simulation and record data at 1,000 ticks, 1,500 ticks, 2,000 ticks, 2,500 ticks, and 3,000 ticks.

6. Reset the simulation, add 10 clouds, and run again for 3,000 ticks, recording the global temperature every 500 ticks in the data table.

7. Reset the simulation again, add CO_2 until you have 300 CO_2 (about 12 clicks) and run again for 3,000 ticks, recording the global temperature every 500 ticks in the data table.

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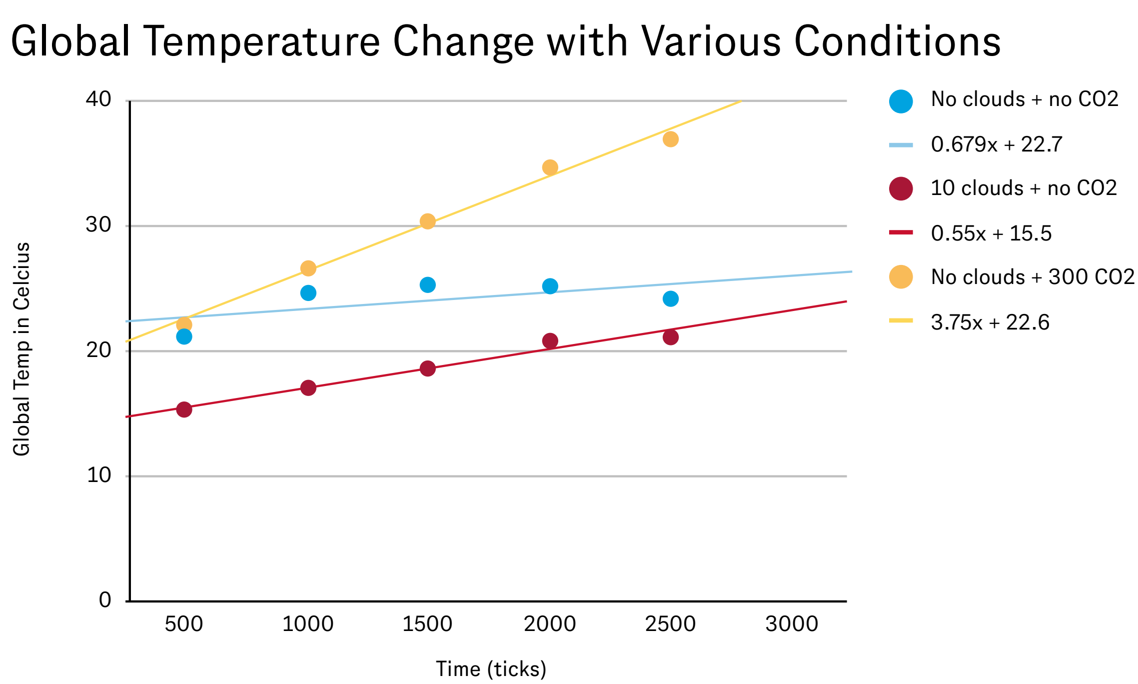
Climate Change Simulation Capture Sheet

ANSWER KEY **Do not share with students**

Continued

Time (ticks)	Global Temperature (˚C) #1 (no clouds, no CO_2)	Global Temperature (˚C) #2 (10 clouds, no CO_2)	Global Temperature (˚C) #3 (10 clouds, 300 CO_2)
0	12˚C	12˚C	12˚C
500	16.04˚C	13.24˚C	16.53˚C
1,000	21.1˚C	15.3˚C	22.17˚C
1,500	24.59˚C	17.01˚C	26.54˚C
2,000	25.22˚C	18.54˚C	30.38˚C
2,500	25.1˚C	20.77˚C	34.67˚C
3,000	24.24˚C	21.19˚C	36.86˚C

Virtual Lab
Graph the global temperature for each scenario from your data table above. Graph as a scatter plot. Make sure to label each axis and draw a line of best fit for each data set. (double click the following graph to edit).



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Climate Change Simulation Capture Sheet

ANSWER KEY **Do not share with students**

Continued

Use your line of best fit to calculate the rate of temperature change for each scenario. Show your work below. (*remember the rate of temperature change = the slope of the line of best fit, rise/run) Global Temperature #1 Rate Calculation:

Equation: $0.679x + 22.7$

Slope: 0.679

0.679/500 = 0.001358

Rate of temp change: 0.001358 degrees/tick

Global Temperature #2 Rate Calculation:

Equation: $1.55x + 15.5$

Slope: 1.55

1.55/500 = 0.0031

Rate of temp change: 0.0031 degrees/tick

Global Temperature #3 Rate Calculation:

Equation: $3.75x + 22.6$

Slope: 3.75

3.75/500= 0.0075

Rate of temp change: 0.0075 degrees/tick

Conclusion Questions:

1. What is an independent variable in this experiment?

The independent variable is the condition of the sky or atmosphere (amount of clouds and CO_2).

2. What is a dependent variable in this experiment?

The dependent variable is the global temperature.

3. How does adding clouds affect the global temperature? Why do you think this happens?

Adding clouds lowers the global temperature, likely because it catches rays before they hit the ground and allows them to bounce back off into the sky instead of going into the ground to be absorbed.

4. How does adding CO_2 affect the global temperature? Why do you think this happens?

Adding CO_2 increases the global temperature, likely because it traps in heat that comes from the sun's rays.

5. Can heat that has entered the ground ever be released? If so, how?

Yes, heat from the ground, or geothermal energy, can be released. Geothermal energy is used across the world, commonly to heat homes and office buildings. It is extracted using geothermal power plants or geothermal heat pumps.

6. What is albedo? Where is a place on Earth you would expect to have high albedo? Low albedo?

Albedo refers to the proportion of light from the sun (or moon) that is reflected from Earth's surface, and is measured on a scale of 0 to 1; 0 being the most absorbent and 1 being the most reflective. Places you would expect to have high albedo would be colder, icy areas, such as the Arctic, because their surfaces are not only light, but also shiny and smooth (ice), allowing it to be more reflective. Places you would expect to have a lower albedo would be forest areas around the equator because there is a lot more darker ground (soil) and more plants and foliage to absorb the heat. Also, you would expect to find a higher albedo in desserts because the surface of the ground is not smooth but rather rough, making it harder to reflect the rays.

7. What do you predict would happen if you set the albedo to "0"? Why?

If the albedo were set to 0, the ground would heat up at an extremely rapid rate, increasing the global temperature very quickly. This is because all of the rays would be absorbed into the ground, and none would be reflected back into the atmosphere. All that energy stored in Earth with none released would make it hotter. The only rays that would be reflected would be the ones that bounce off the clouds.

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Climate Change Simulation Capture Sheet

ANSWER KEY | **Do not share with students**

Continued

8. Create a claim to answer the following question and support your claim with evidence and reasoning.

   Question:
   What are the factors that affect climate change and how does each affect solar rays?

Claim:

Clouds, CO_2, and albedo affect climate change. Clouds and high albedo decrease global temperature, and CO_2 and low albedo increase global temperature.

Evidence: What patterns do you observe in your data.	Reasoning: How do these patterns support your claim?
When there are clouds and no CO_2, the global temperatures are generally lower, ranging from 12–22°C. When there is a lot of CO_2 in the air, but no clouds, the global temperature increases at a rate of 0.0075 degree/tick. When the albedo is set to 1, all the rays bounce off the ground and none are absorbed.	When there is no CO_2, but a lot of clouds, the global temperature range is generally lower than the other conditions. This is due to clouds allowing another source for solar rays to bounce off, preventing them from being absorbed by the ground. When there is a lot of CO_2, but no clouds in the air, the global temperature increases at the fastest rate. This is due to the fact that CO_2 in the atmosphere traps heat, allowing the global temperature to increase faster. When the albedo is set to 1, the global temperature does not increase. This is because the ground's surface reflects every ray, so there is no chance the energy from the rays can be absorbed and stored in the ground.

Greenhouse Gas Emissions from Large Facilities Capture Sheet

ANSWER KEY — **Do not share with students**

Microbes, CO_2 and You!
As previously discussed, CO_2 is a greenhouse gas and fluctuating levels of CO_2 will cause changes in global temperatures. It is therefore imperative that we are able to identify sources emitting high amounts of CO_2, invest in new technology that is able to control CO_2 emissions, and be able to utilize this technology in real-world facilities.

Read the *Using Microbes for CO_2 Emissions Reading*, then answer the following questions.

1. What is the function of a carboxysome?

It is a cellular compartment where CO_2 is captured.

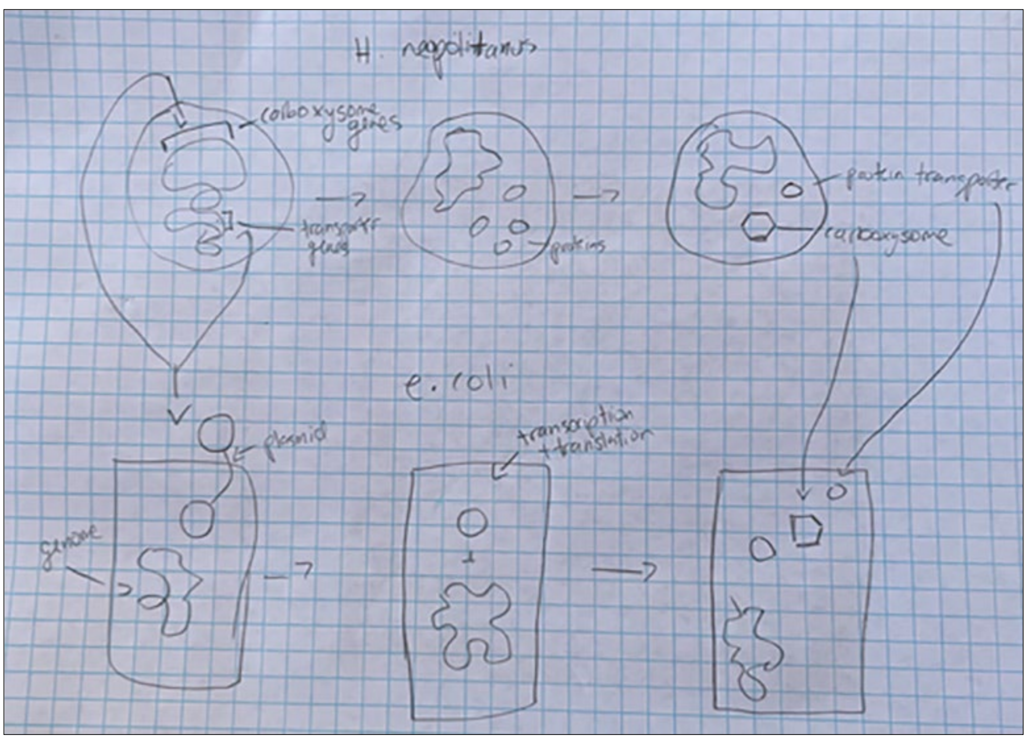
2. Why do organisms that rely on atmospheric carbon need a carboxysome?

Because it is the part of the cell that allows the organism to store and use CO_2.

3. When trying to create bacteria that can process CO_2, why is it important to remove genes that allow bacteria to process sugar?

If the bacteria can process sugar, they do not need to collect CO_2 and will grow normally without it. In order for them to actually collect CO_2, they need to have no other option for gaining energy.

4. Draw a model to illustrate how bacteria, such as H. neopolitanus or *E. coli*, are able to make proteins that allow them to sequester CO_2. In your model, make sure to include the following labels: transcription, translation, genes, proteins, genome/plasmid, transporter.



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Greenhouse Gas Emissions from Large Facilities Capture Sheet

ANSWER KEY — **Do not share with students**

Continued

5. How is "green chemistry" demonstrated with microbes?

"Green chemistry" is the process of using bio-engineered organisms to perform chemical reactions that would cut back on environmental hazards. In this case, *H. neopolitamus* and *E.coli* are used to take CO_2 out of the atmosphere with the use of carboxysomes.

6. What are four examples of products we could possibly make out of microbes?

chemicals, biofuels, additives for food, and bulk edible protein

Your Local CO_2 Emissions

Now that we know more about potential solutions for rising CO_2 emissions, how can we identify where sources of CO_2 emissions are located in our community? Visit the following website: *Welcome To The Green House Gases Mobile Website.*

Continues next page >

Greenhouse Gas Emissions from Large Facilities
Capture Sheet

ANSWER KEY **Do not share with students**

Continued

1. Select your state and choose CO_2 as the greenhouse gases from the list. Press APPLY SEARCH (this will allow you to select your county)

2. What are the total emissions for your state? (include the units!)

84 Million Metric Tons CO_2e

3. Select your county. What are the total emissions for your county?

2,391,887 Metric Tons CO_2e

4. How does your county compare to other counties in your state? What percent of state emissions come from your county?

My county makes up for around 2.847% of the emissions of California in total.

Teacher note—answers vary by county.

5. What sector emits the most CO_2 in your county?

Power plants emit the most CO_2 in my county.

Teacher note—answers vary by county.

6. How many companies emit CO_2 in your county?

14 companies

Teacher note—answers vary by county.

Continues next page >

Greenhouse Gas Emissions from Large Facilities Capture Sheet

ANSWER KEY **Do not share with students**

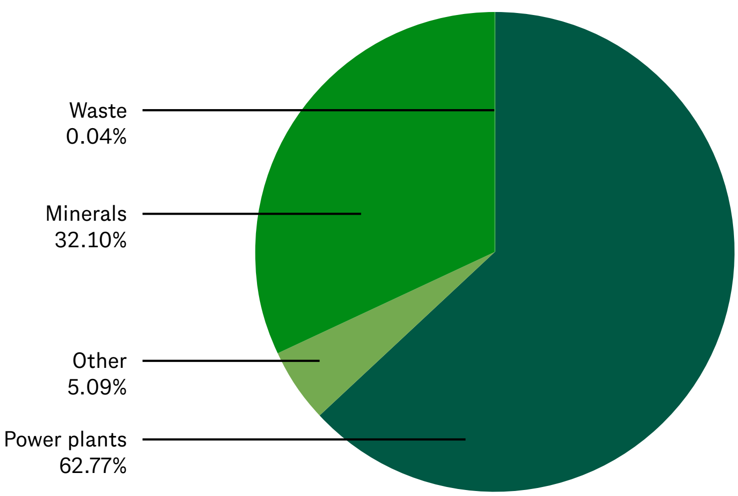
Continued

7. Fill in the following data table for your county.

Teacher note—answers vary by county.

Power Plants	Petroleum and Natural Gas Systems	Refineries	Chemicals	Other	Minerals	Waste	Metals	Pulp and Paper
1,501,381	0	0	0	121,739	767,839	928	0	0

8. Use the data above to make a pie chart in a Google spreadsheet. Copy and paste your chart below.



9. What are the highest producing sectors in your county?

The highest producing sectors are power plants and minerals.

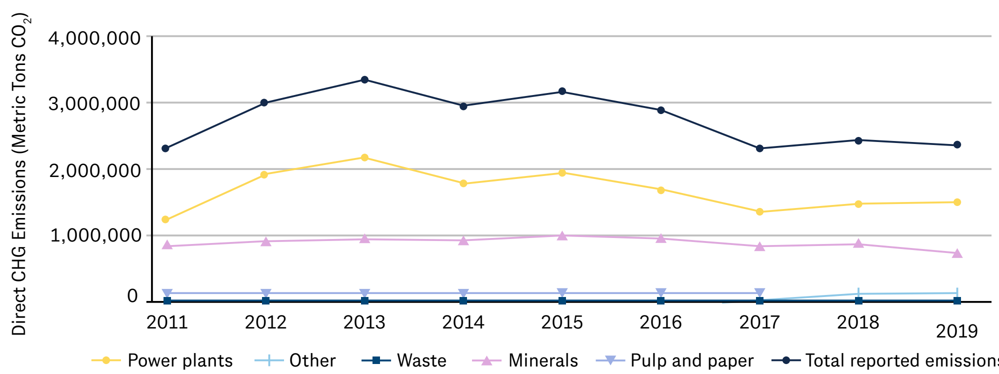
10. Click on "Trends" and draw a quick sketch/insert a screenshot of the graph illustrating the change in CO_2 emissions over time in your county. Describe trends you observe.

Continues next page >

Greenhouse Gas Emissions from Large Facilities Capture Sheet

ANSWER KEY — **Do not share with students**

Continued

Graph	California—Direct CHG Emissions of Selected Cases Reported by Sector in Metric Tons of CO_2 (2011–2019) 
Observations	The total reported emissions increased from 2011–2013, then started slowly declining until 2019. There has been some fluctuation in the decline and areas where it increased slightly, but it never increased more than the total in 2014. The total power plants emissions follows this general trend, but the emissions from other sources remains fairly constant aside from a slight decrease from 2017–2019.

11. Give the name of 2–3 example facilities that operate in your state or county (find 2–3 with the highest emissions, to do this you may want to switch to "list view" instead of "map view").

Answers will vary.

12. Describe how greenhouse gases are released in the facilities you identified (you may have to research on other websites).

Sample answer:
Hanson Permanente Cement:
Hanson Permanente Cement is a cement contractor. In order to make cement, limestone needs to be baked into lime, which releases large amounts of CO_2.

Teacher note—answers vary by county.

13. Research these facilities, such as by finding their own websites to see what processes are occurring. Identify the importance of these facilities to your community. Do these facilities benefit all members of the community? Are there people in the community that are not benefitting from these facilities? What could be done to improve access to these benefits to all members of the community?

Regional Wastewater Facility.
Hanson Permanente Cement: This facility is important to the community for building infrastructure. The facility itself is not located in Cupertino City, so the city cannot impose conditions on it. This limits accessibility and does not regard desires/concerns of the city residents.

Lehigh Quarry and Cement Plant Info

Microbes to the Rescue Capture Sheet

ANSWER KEY **Do not share with students**

Currently Implemented CO_2 Capturing Tech

If you were trying to convince a company to change procedures or regulations, the company may be resistant to your ideas. One way to get someone on your side is to show them examples of other companies that have already implemented your ideas and how those companies have benefitted. Use the following reading to identify 2–3 facilities that have utilized technology to reduce emissions and explain how each has benefited: *Capturing Carbon's Potential: These Companies Are Turning CO_2 into Profits.*

Facility Name (Teacher note: Answers vary).	Benefits of Capturing CO_2
Newlight Technologies	Turns CO_2 from air into a bioplastic *Uses a microbe-based biocatalyst to pull carbon from methane or carbon dioxide*
Econic	Uses catalyst technologies to convert CO_2 into polyols *(short chain polymers)*
NovoNutrients	Uses CO_2 from industrial emissions to feed lab created bacteria *(then, the bacteria produce a protein similar to that of fish, essentially replacing fishmeal and feeding the fish on fish farms)*

Who is Affected by Climate Change?

Although climate change is a global issue, some people are more affected than others depending on where they live and their ability to cope with different climate hazards. Use the following link to identify different groups of people that are more vulnerable to the effects of climate change and explain the hardships these people face resulting from climate change: *Climate Impacts on Society | Climate Change Impacts*.

	Geographic Location	Indiginous People	Urban Populations
Specific examples of vulnerable populations	• people in coastal areas • people in southern and western United States • people in the mountain west • arctic residents	• tribes living in rural or coastal areas • people relying on surrounding environment and natural resources for food • uninsured individuals • people living in isolated or low income communities	• people living in dense cities/densely populated cities
Hardships these people face resulting from climate change	• coastal storms, air pollution, drought, heat waves • water shortages • increased risk of wildfire • high demands on transportation, water, energy	• limited access to natural resources or food—will restrict traditional food or cultural practices • lots of health detriments • water quality problems • threats to cultural identities and lifestyle	• increases in heat waves • increased risk of drought and violent storms • aging infrastructure • problems with transportation/ sewage/ drainage/ water supply

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Microbes to the Rescue Capture Sheet

ANSWER KEY — **Do not share with students**

Continued

Share Awareness
Create a way to socially communicate (Instagram/Facebook/Snapchat with filter/Tiktok/email the company directly) the following information:

— Local sources of high CO_2 emissions
— How microbes can recycle CO_2 from the air
— Other companies that have already used this tech and how they have benefitted
— *Who will this technology help?* Who is most affected by climate change?

(You must make something that can be turned in, so if you are filming yourself, make sure you record, if you are posting a status, take a screenshot, if you are emailing make a copy, etc.)

If you have a picture of your work, insert below. If you have a film, attach it as a separate file.

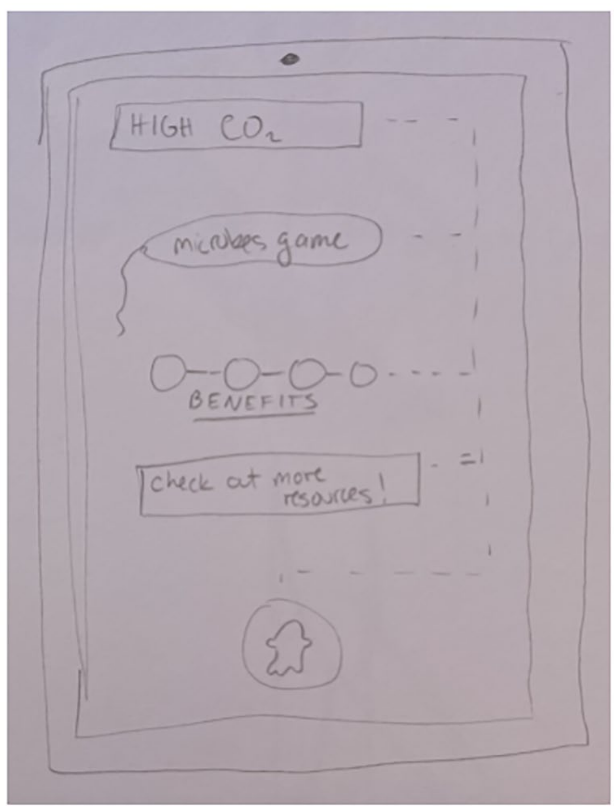
This is a basic sketch of a Snapchat filter to share awareness. Once you access the filter, four different options show up on the screen.

When you click on the first one, it will display a slideshow of local images of locations where there are high CO_2 emissions.

When you click on the second option, there will be a game you can play that walks you through the process of how *H. neopolitamus* and *E.coli* can use carboxysomes to recycle CO_2 from the air. Once you complete the game, the filter will give you an option to take a selfie with little microbe friends on the snap screen!

When you click on the third option, there will be a list on screen of different companies that have already used this tech. You can click on any company to see how they have benefited.

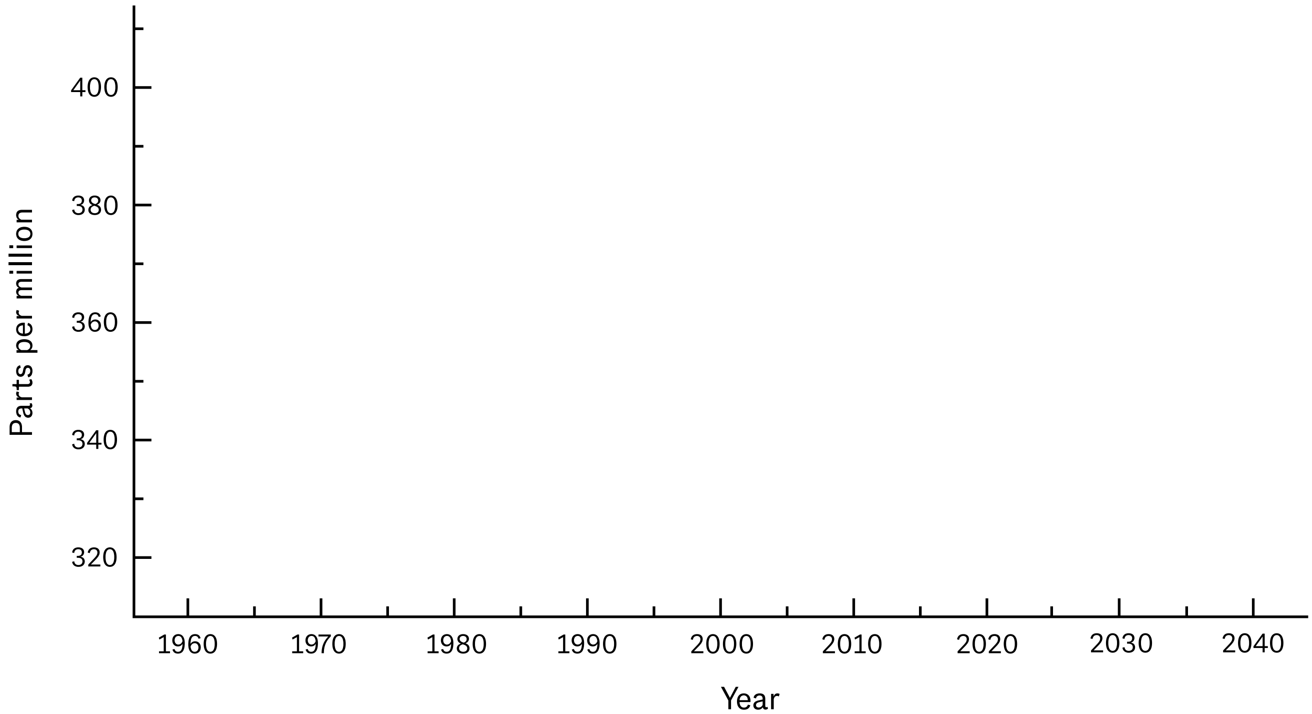
When you click on the fourth option, it will redirect you out of the app to a website (perhaps the one linked above) so you can check out in more detail who is affected by climate issues and how they will benefit from the new methods.



FUTURELAB+

CO_2 Data Extrapolation Capture Sheet

Atmospheric CO_2 at Mauna Loa Observatory



1. Identify the axes in the graph above.

2. What are the units used to measure CO_2?

3. What does this unit mean?

4. Replicate the data from 1960-1980 provided by your teacher in your graph.

5. Draw a line predicting what the data may look like from 1980–2000.

6. Replicate the data from 1960-2000 provided by your teacher in your graph.

7. How did your prediction compare to the actual data? How does this make you feel?

8. Now make a final prediction. Draw a line to illustrate what you think the data from 2000–2018 will look like.

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CO_2 Data Extrapolation Capture Sheet

Continued

9. Replicate the data from 1960-2020 provided by your teacher in your graph.

10. How did your prediction compare to the actual data? How does this make you feel?

11. Do you think the graph illustrates consistent data? Explain with evidence.

12. What is a pattern you can observe in the graph? Why do you think this pattern exists?

13. Go to the *En-Roads* website. Looking at the graph on the right, to what are emissions linked?

14. Change the graph on the left on En-Roads so you are looking only at CO_2 emissions. Screenshot your En-Roads virtual lab simulation and place it in the space below, showing what you chose to manipulate to get the global temperature down by 1.5˚C by 2050. Draw your extrapolation for data until 2040 on the graph above.

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Climate Change Simulation Capture Sheet

Virtual Lab
Go to the following website: *NetLogo Web*.

We will investigate how solar energy interacts with Earth systems and the factors that affect climate change.

Procedure

1. Open the virtual lab.
2. Set the following parameters:
   - Click "Set-up."
   - Set sun-brightness to 1.0.
   - Set albedo (how much light is reflected by the surface) to 0.50.
   - Click the "add cloud" button four times.
   - Click the "add CO_2" button four times.å
3. Click "Go." Click the "Watch a ray button" and see what happens to the sun's rays to answer the following questions. You may need to watch multiple rays to answer all the questions.

   a. What are the possible outcomes as the rays hit the ground?

   b. How do the rays interact with the clouds?

   c. What happens to the rays that have entered the ground?

   d. Set the "albedo" to 1.00. What happens now as the sunlight hits the ground?

   e. Where on Earth would be similar to an albedo of 0.50? Where would be similar to an albedo of 1.00?

4. Reset the simulation with no clouds and no CO_2 keeping the albedo set at 0.5. Click "Set up" and "Go".
5. Allow the simulation to run until you get to 500 ticks, and then pause the simulation to record the global temperature in the following data table. When finished recording data, resume. Run the simulation and record data at 1,000 ticks, 1,500 ticks, 2,000 ticks, 2,500 ticks, and 3,000 ticks.
6. Reset the simulation, add 10 clouds, and run again for 3,000 ticks, recording the global temperature every 500 ticks in the data table.
7. Reset the simulation again, add CO_2 until you have 300 CO_2 (about 12 clicks) and run again for 3,000 ticks, recording the global temperature every 500 ticks in the data table.

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Climate Change Simulation Capture Sheet

Continued

Time (ticks)	Global Temperature (°C) First simulation (no clouds, no CO_2)	Global Temperature (°C) Second simulation (10 clouds, no CO_2)	Global Temperature (°C) Third simulation (10 clouds, 300 CO_2)
0	12°C	12°C	12°C
500			
1,000			
1,500			
2,000			
2,500			
3,000			

Virtual Lab
Graph the global temperature for each scenario from your data table above. Graph as a scatter plot. Make sure to label each axis and draw a line of best fit for each data set.

Continues next page >

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Climate Change Simulation Capture Sheet

Continued

Use your line of best fit to calculate the rate of temperature change for each scenario. Show your work below. (*Remember the rate of temperature change = the slope of the line of best fit, rise/run).

Global Temperature #1 Rate Calculation:

Global Temperature #2 Rate Calculation:

Global Temperature #3 Rate Calculation:

Conclusion Questions:

1. What is an independent variable in this experiment?

2. What is a dependent variable in this experiment?

3. How does adding clouds affect the global temperature? Why do you think this happens?

4. How does adding CO_2 affect the global temperature? Why do you think this happens?

5. Can heat that has entered the ground ever be released? If so, how?

6. What is albedo? Where is a place on Earth you would expect to have high albedo? Low albedo?

7. What do you predict would happen if you set the albedo to “0”? Why?

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Climate Change Simulation Capture Sheet

Continued

8. Create a claim to answer the following question and support your claim with evidence and reasoning.

   Question:
   What are the factors that affect climate change and how does each affect solar rays?

Claim:

Evidence: What patterns do you observe in your data.	Reasoning: How do these patterns support your claim?

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Using Microbes for CO_2 Emissions Reading

Modified from: IGI Scientists Make E. coli That Can Take Carbon Dioxide From the Air — And Use It

Rising levels of atmospheric CO_2 are contributing to climate change and global environmental destruction. Recently, researchers from the Innovative Genomics Institute from Dave Savage's lab at UC Berkeley have engineered *E. coli* to absorb and concentrate carbon dioxide in the air. This is a major breakthrough in carbon sequestration, or carbon storage, by removing atmospheric carbon dioxide and lessening the effects of climate change. Carbon is an essential building block of all organic molecules and serves as a fuel source for cellular metabolism. Many organisms, including humans and *E. coli*, receive carbon through food, usually by eating simple sugars and starches. Plants and microorganisms use photosynthesis to remove carbon from CO_2 in the atmosphere. Carbon is not abundant in Earth's atmosphere, comprising only 0.04% total. Therefore, organisms cannot easily rely on atmospheric CO_2 to function. Cellular compartments, known as carboxysomes, allow microorganisms to concentrate CO_2 as fuel storage. Engineering organisms to have carboxysomes allows them to capture CO_2, and has major implications on the environment, agriculture, and chemical engineering. Previous work in the Savage lab has identified the genes needed to encode a functional carboxysome in a microorganism, such as *E. coli* bacteria. Researchers in the Savage lab engineered bacteria, which do not normally concentrate CO_2, to rely on carboxysomes to get the carbon they normally receive through their diet by removing the genes required to process sugars. This causes *E. coli* to need another source of carbon, such as CO_2, as their primary food source. To receive enough carbon, the transporter and carboxysome must work together effectively to remove atmospheric carbon dioxide. To their amazement, the researchers observed that their experiment worked and the carbon dioxide-concentrating genes from *H. neopolitanus* proved to be an effective method to concentrate carbon dioxide from the atmosphere. Breakthroughs in CO_2-concentrating technology bring us closer to slowing climate change even though the applications are not yet known. This technology might even be used to engineer crops to grow bigger, faster, while also reducing water and fertilizer usage.

This technology has the potential to capture CO_2 from the atmosphere while also fortifying food sources to feed the growing global population with fewer farm inputs. This technology will also affect how chemicals are used in commercial agriculture and the field of "green chemistry." "Green chemistry" uses engineered organisms to perform chemical reactions without contributing to carbon dioxide emissions. The Savage lab and collaborators are continuing to research how carboxysomes and CO_2 transporters can be relevant to industrial microorganisms. Potential applications they are exploring are biofuels, chemicals, additives for food, bulk edible proteins, and imitation meats.

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Greenhouse Gas Emissions from Large Facilities
Capture Sheet

Microbes, CO_2, and You!
As previously discussed, CO_2 is a greenhouse gas and fluctuating levels of CO_2 will cause changes in global temperatures. It is therefore imperative that we are able to identify sources emitting high amounts of CO_2, invest in new technology that is able to control CO_2 emissions, and utilize this technology in real-world facilities.

Read the *Using Microbes for CO_2 Emissions Reading*, then answer the following questions.

1. What is the function of a carboxysome?

2. Why do organisms that rely on atmospheric carbon need a carboxysome?

3. When trying to create bacteria that can process CO_2, why is it important to remove genes that allow bacteria to process sugar?

4. Draw a model to illustrate how bacteria, such as *H. neopolitanus* or *E. coli*, are able to make proteins that allow them to sequester CO_2. In your model, make sure to include the following labels: transcription, translation, genes, proteins, genome/plasmid, transporter.

Continues next page >

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Greenhouse Gas Emissions from Large Facilities Capture Sheet

Continued

5. How is "green chemistry" demonstrated with microbes?

6. What are four examples of products we could possibly make using microbes?

Your Local CO_2 Emissions

Now that we know more about potential solutions for rising CO_2 emissions, how can we identify where sources of CO_2 emissions are located in our community? Visit the following website: *Welcome To The Green House Gases Mobile Website.*

Continues next page >

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Greenhouse Gas Emissions from Large Facilities Capture Sheet

Continued

1. Select your state and choose CO_2 as the greenhouse gas from the list. Press APPLY SEARCH (this will allow you to select your county).
2. What are the total emissions for your state? (Include the units!)

3. Select your county. What are the total emissions for your county?

4. How does your county compare to other counties in your state? What percent of state emissions come from your county?

5. What sector emits the most CO_2 in your county?

6. How many companies emit CO_2 in your county?

Continues next page >

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Greenhouse Gas Emissions from Large Facilities Capture Sheet

Continued

7. Fill in the following data table for your county.

Power Plants	Petroleum and Natural Gas Systems	Refineries	Chemicals	Other	Minerals	Waste	Metals	Pulp and Paper

8. Use the data above to make a pie chart in the circle below.

9. What are the highest producing sectors in your county?

10. Click on “Trends” and draw a quick sketch or insert a screenshot of the graph illustrating the change in CO_2 emissions over time in your county. Describe trends you observe.

Continues next page >

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Greenhouse Gas Emissions from Large Facilities
Capture Sheet

Continued

Graph	
Observations	

11. Give the name of two to three example facilities that operate in your state or country. (Find two to three with the highest emissions.) To do this, you may want to switch to "list view" instead of "map view."

12. Describe how greenhouse gases are released in the facilities you identified (you may have to research on other websites).

13. Research these facilities, such as by finding their own websites to see what processes are occurring. Identify the importance of these facilities to your community. Do these facilities benefit all members of the community? Are there people in the community that are not benefitting from these facilities? What could be done to improve access to these benefits to all members of the community? Choose one facility and answer these questions in terms of that facility.

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Microbes to the Rescue Capture Sheet

Currently Implemented CO_2 Capturing Tech

If you were trying to convince a company to change procedures or regulations, the company may be resistant to your ideas. One way to get someone on your side is to show them examples of other companies that have already implemented your ideas and how those companies have benefitted. Use the following reading to identify two to three facilities that have utilized technology to reduce emissions and explain how each has benefited: *Capturing Carbon's Potential: These Companies Are Turning CO_2 into Profits.*

Facility Name	Benefits of Capturing CO_2

Who is Affected by Climate Change?

Although climate change is a global issue, some people are more affected than others depending on where they live and their ability to cope with different climate hazards. Use the following link to identify different groups of people that are more vulnerable to the effects of climate change and explain the hardships these people face resulting from climate change: *Climate Impacts on Society | Climate Change Impacts.*

	Geographic Location	Indiginous People	Urban Populations
Specific examples of vulnerable populations			
Hardships these people face resulting from climate change			

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FUTURELAB+

Microbes to the Rescue Capture Sheet

Continued

Share Awareness

Create a way to socially communicate (Instagram/Facebook/Snapchat with filter/Tiktok/email the company directly) the following information:

— Local sources of high CO_2 emissions
— How microbes can recycle CO_2 from the air
— Other companies that have already used this tech and how they have benefitted
— *Who will this technology help?* Who is most affected by climate change?

(You must make something that can be turned in, so if you are filming yourself, make sure you record; if you are posting a status, take a screenshot; if you are emailing make a copy, etc.)

If you have a picture of your work, insert below. If you have a film, attach it as a separate file.

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Career Profile

Ryan Tappel, PhD
Senior Scientist of Synthetic Biology and Entomology
LanzaTech

What do you do and how did you get here?

The thing that motivated me to pursue science in general was my love of the environment and wanting to do something that feels meaningful to help address global climate change. During my PhD, I worked on creating new plastics that bacteria could degrade, but afterwards it was hard to find a job in environmental related research. I kept in touch with a friend who happened to start work at LanzaTech, and when he told me that they were hiring I said I would definitely love to interview. I love the mission of LanzaTech—to renew waste material. In this case, the waste is gasses like carbon monoxide and carbon dioxide. Instead of pumping them into the atmosphere, we capture them and use bacteria to eat those gasses to make different things. My role in the company is to engineer the bacteria to perform better and make new products.

What was your favorite subject in high school, and why did you love it?

Science! (Chemistry and Physics). I loved it because I had an excellent teacher whom I was comfortable with. I enjoyed the hands-on approach of the classes. Followed closely by History where I had another excellent teacher who pushed me to develop numerous adult/college-level skills that served me well.

If you could give a piece of advice to your younger self, what would it be?

To my high school self: first some comfort. It's okay that you don't know what you are doing, but keep trying new things. I did a lot of "wandering around" in college, not really knowing what I wanted to do. And that's ok! I'd remind myself to strive to be hardworking and kind.

What skills do you use on a daily basis?

I use chemistry, algebra, and organizational skills on a regular basis while doing DNA and protein sequence analysis. I also use conversational skills when presenting at conferences, meeting new people and conducting meetings, for example. There's just so much science to talk about!

What's most fulfilling about your job/ career? What's most challenging?

I hoped for a long time I would get to work in a setting where addressing global climate change was a core value, and I have found that at LanzaTech. What is challenging is managing the fast-pace and intensity of the projects we work on.

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FUTURELAB+

Career Profile

Continued

If you could have any superpower, what would it be?

I'd love to be able to bioengineer myself to have spider-like abilities. I want to crawl up walls!

If you could instantly learn any language, which would you choose and why?

Chinese. It is the most-spoken language along with English, and I'd love to be able to communicate with more people.

Favorite place to go?

I live in Chicago, and love visiting The Field Museum!