ON THE AIR

2020

CLEAN AIR PARTNERS
DC-MD-VA

A Middle School Air Quality Curriculum Resource

ON THE AIR 2020

Developed By:
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DBY
STEM Education
Services

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Produced By:

CLEAN AIR PARTNERS
DC-MD-VA

Introduction

Twelve years ago, Clean Air Partners released the original On the Air curriculum as a way to help educators bring air quality stewardship to life for middle school students in the Washington D.C.-Maryland-Virginia region. This revised version of On the Air continues that commitment to supporting local educators in their efforts to teach a new generation of informed, active young people about their role in protecting themselves and our planet from air pollution. Welcome to On the Air 2020!

Much has changed since the original On the Air was released: new science standards have been adopted, and new perspectives on STEM education have developed. The same is true for the atmosphere: while local levels of many common air pollutants have decreased, climate changed has become even more of a pressing issue as greenhouse gas levels and the global temperatures continue to rise. This continual change is what prompted the need to update On the Air. So what can you expect from On the Air 2020?

- 5 modules aligned to the Next Generation Science Standards, the Virginia Standards of Learning (SOL), and the Common Core State Standards for Math & Literacy
- Inquiry-based 5E lesson sequences built around local phenomena
- Engaging and interactive lessons with a wide variety of student-centered activites
- Media and technology-rich experiences that enhance student learning
- A web-based interactive platform for accessing and implementing the curriculum

The 5 modules that comprise the curriculum revolve around key concepts in air quality:

- Module 1 uses modeling to investigate how ozone pollution affects human by systems
- Module 2 looks at how human activities and weather influence short and long-term trends in air quality
- Module 3 focuses on the effect of particulate matter on the health of a community
- Module 4 investigates the connection between air quality and water quality in the Chesapeake Bay
- Module 5 centers on climate change and the role of air pollution in rising sea levels

In the pages that follow, you'll find more about the curriculum itself and how to use it in your classroom. Explore it here or online, as you figure out how your students can play a part in making the air safe to breathe in 2020 and beyond.

Thank you!

- David Yarmchuk, Curriculum Developer for On the Air 2020

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Guidelines for Teaching On the Air

On the Air 2020 is a standards-aligned air quality curriculum that was created to support inquiry-based science education for students in grades 5-12. This section includes a variety of information to help you implement On the Air 2020 successfully. For more details about how to use the curriculum, visit http://ontheair.cleanairpartners.net/how-to-use.

To access all of On the Air 2020 online go to: http://ontheair.cleanairpartners.net

How is On the Air 2020 structured, and how should I use it?

5 Independent Modules: On the Air 2020 has 5 modules, which are each made of one complete 5E lesson sequence. These lesson sequences range from 9-13 activities, and all include a summative assessment. The modules can be used independently, or as a complete unit. The order of the modules is intentional, so it is recommended that you teach the modules in order if you plan to teach them all.

Scientific Phenomena & Engineering Problems: On the Air 2020 is built around explaining scientific phenomena and designing solutions to engineering problems. The Next Generation Science Standards (NGSS) and the Virginia Standards of Learning (SOLs) focus on engaging students in these practices of science and engineering as a way to foster authentic science learning. While these are not the only science and engineering practices that students undertake in standards-aligned science curricula, they are critical components of NGSS and the SOLs. Each module in the curriculum explicitly details the phenomena that students are looking to explain or the engineering problems they are looking to solve. When in doubt about how to teach the module, make sure that the scientific phenomena and engineering problems are at the forefront.

Teach Whole Modules: Because each module of On the Air is a complete 5E lesson sequence that leads students to explore and explain a phenomenon related to air quality, students will learn best if they progress through the modules as designed, from engaging with and exploring the phenomenon, to developing explanations, to elaborating and extending their understanding, to an evaluation of their learning. Pulling individual pieces out of each module will short-circuit this cycle of inquiry and prevent students from experiencing the full richness of the modules.

Adopt & Adapt: While we love the activities in On the Air 2020 that doesn't mean they're perfect for every classroom around the world. Where necessary, make adjustments to better suit your students or your classroom situation. That might mean adding in a mini-lesson here or there to fill in gaps in student understanding or skills, reteaching a lesson that students need more support with, swapping out a video, tweaking a handout, or adjusting the pacing. With that said, there is an intentionality built into each module and activity, so keep that in mind before you make sweeping changes to the curriculum.

Connect to online materials and resources: The online version of On the Air 2020 has embedded images and videos that you can show directly through the website. You can also download print materials for the curriculum, including student handouts (in both pdf and Word formats) and teacher guides. Access the website at: http://ontheair.cleanairpartners.net.

What common structures and practices will I see in On the Air 2020?

Activities that follow the 5E model of instruction: The 5E instructional model is a student-centered method for teaching science and engineering through guided inquiry. The model gets its name from the 5 stages that students progress through when they are following the model: Engage, Explore, Explain, Elaborate, Evaluate. The model was developed by Biological Sciences Curriculum Study (BSCS) in 1978 as a tool for science educators to plan meaningful lessons and units. To learn more about the origins and adaptations of the 5E model, visit the BSCS 5E webpage.

Claim-Evidence-Reasoning for scientific writing: The Claim-Evidence-Reasoning (CER) structure is used throughout On the Air 2020 as a way to support student thinking, sensemaking, and scientific writing. It is a helpful method for improving students' analytical skills when it comes to interpreting data and expressing conclusions. Learn more about the CER model by watching this video from Bozeman Science: https://www.youtube.com/watch?v=5KKsLuRPsvU.

Anchor charts: Each module in On the Air 2020 is designed to be a coherent learning sequence. Phenomena, questions, concepts, and information form through-lines that enhance student sensemaking and understanding. Anchor charts that teachers and students create together and then display in the classroom throughout the unit serve as reference points and "anchors" to guide that sensemaking.

"Know-Want to Know-Learned: (KWL) charts and "I see, I think, I wonder" charts: As students progress through a module in the curriculum, they perform the same kinds of activities that scientists do in the real world. This starts with making observations, connecting observations to background information, raising questions, exploring those questions, and reflecting on learning. KWL charts and I see, I think, I wonder charts provide students with the opportunity to engage in authentic exploration and learning, and reflect on that process.

What information is in each module?

On the Air 2020 modules have a common structure. Each module contains the following information:

- **Module overview**: a brief description of the module contents in narrative form
- **When to teach this module:** guidelines for incorporating On the Air 2020 into your current curriculum or scope & sequence
- **Standards overview**: how the module aligns to NGSS, VA SOL, and Common Core standards
- **5E module flow:** the purpose, timing, and objectives for each activity in the module
- **Module materials:** what handouts or other materials are required to teach each activity
- **Teacher background information:** helpful information for teachers to use to prepare for the module, and links to additional sources
- **Module activities:** directions for teaching each activity, as well as student handouts and teacher guides
- **Doing our part:** a set of actions that students can take to improve air quality in their communities or to keep themselves safe from air pollution. In Modules 4 & 5, this section is built into one of the activities as opposed to being a separate section.
- **Air quality champion in the community:** an interview with a member of the community who works to support healthy air

Note: Module 4 contains additional information including: What is a MWEE, how to fund the module, and special timing considerations.

What does a typical activity page look like?

A typical page from On the Air 2020 looks like this:

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Activity 2 (Explore): Introducing the Chesapeake Bay

Activity overview

Activity summary: In this activity, students get to know the Chesapeake Bay a little better by watching a video, looking at maps, and reading an article. The goal is for students to develop greater familiarity and connection with the Bay, while also learning some important facts for their investigation.

Activity standards

Standards Connection

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience

Blue boxes have important information for teaching the activity successfully

A Note About Place-Based Learning

Students may have a conceptual idea of the Bay, or they may have seen it when they rode over the Bay bridge, but few of them have the strong internal connection for the Bay that many conservationists have. Be sure to help students develop some of that connection, which goes beyond the technical definition of what they Bay is. The video students watch in this activity is designed to help with that. You may also consider putting up pictures of the Bay around the classroom during this module to help students build that connection, or even scheduling a trip with organizations like CBF to take students to the Bay.

Activity directions are written out in detail and often include images or links to videos

Warmup: What do you know about the Chesapeake Bay?

- This warmup is designed to provide some information on students' background knowledge about the Bay. Some students may have a lot of background knowledge, and some will likely have none. Encourage all students to write something (ex. all students should know that it has water in it). Have students share after the warmup so that others can benefit from their background knowledge. You may want to look at students' answers beforehand and ask a few students to share specific important information.

1. **Frame the activity:** Remind students that they all know different things about the Chesapeake Bay. Tell them that in order for them to solve the mystery of what killed the fish in the Bay, it would help for everyone to know a little more about the Bay. If students included questions in Activity 1 that relate to knowing more about the Bay, connect today's activity back to answering those questions.

ACTIVITY DETAILS

Time: 45 minutes

Objectives

- ✓ Students will know key information about the Chesapeake Bay
- ✓ Students will develop questions about the Chesapeake Bay

Materials

- ✓ Projector & speakers
- ✓ Chart paper (or other way to display document)

Handouts

- ✓ I see & hear, I think, I wonder: The Chesapeake Bay (with teacher guide)
- ✓ About the Chesapeake Bay reading

Modification

- ✓ For the warmup, put butcher paper out on a table (or tables) and have students write whatever they know about the Chesapeake Bay on it. Have enough paper so that all students can write on it at the same time.

The sidebar has information about activity, including teacher tips, differentiation, extensions, and additional resources

On the Air 2020 Module 4: Air and the Chesapeake Bay

After the activity directions, student handouts and teacher guides are included at the end of each activity.

Module Overviews

Module 1: Our Lungs, Our Air, Our Health

The Effects of Ozone Pollution on Human Body Systems

Anchor phenomenon: Two students who are having difficulty breathing.

The air we breathe provides us with the oxygen we need to survive, but it can also introduce dangerous and harmful chemicals into our lungs and our bodies. In this module, students will take on the role of medical professionals to investigate the phenomenon of an asthma attack. They will begin by studying the structure and function of the human respiratory system, and how it connects to the circulatory system. They will use this understanding to develop a model of how our bodies get and transfer oxygen to our cells. Then they will investigate the effects of ground-level ozone and its role in exacerbating the effects of asthma. They will also have the opportunity to connect this understanding with a common treatment for asthma. Finally, students will demonstrate what they know by using their models to show how air pollution affects the human body.

Module 2: What's the Forecast?

Humans, Weather, and the Story of a Code Red Day

Anchor phenomenon: A hazy day that occurred in Washington D.C. in July, 2018.

This photograph of Earth, commonly known as "The Blue Marble," was taken by the crew of the Apollo 17 spacecraft. When humans first began taking pictures of Earth from space in the 1960s, air and water pollution had already become huge problems in the United States. Photographs like this one, as well as books like Silent Spring by Rachel Carson, inspired people to take action to save the planet. In 1970 the first Earth Day was held and the Clean Air Act was signed. The modern environmental movement was born. Since then, humans have done a lot to both damage and protect the Earth and its air. In this module, students will investigate a "bad air day" to understand the sources and types of man-made air pollution, focusing on ozone, a common contributor to bad air days in the region. They will also learn about weather, and the complex ways in which weather and air pollution interact. In doing so, they will use the same sophisticated computer models that meteorologists use to predict both the weather and air pollution. Students will also take a historical look at how air quality has changed over time, using both the Air Quality Index (AQI) and EPA data as guides. As a culminating activity, students will use what they have learned to create an air quality report to inform the public about whether their air is safe to breathe.

Module 3: Air Pollution in the Community

Combustion, Particulate Matter, and Community Health

Anchor phenomenon: Streams of particulate matter emitted from diesel vehicles.

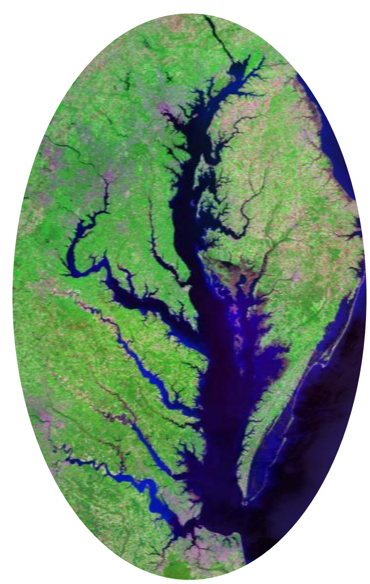
Burning fuel, the chemical process of combustion, has been a part of human civilization since we first started using fire for warmth and cooking. When the Industrial Revolution provided us electricity through widespread use of coal-burning power plants, combustion brought all new benefits, and many serious drawbacks. The advent of cars and trucks driven by internal combustion engines multiplied these effects. Combustion produces particulate matter, a form of air pollution that can have very serious repercussions for human health and the environment. In this module, students will take on the role of concerned community members who fear that their proximity to sources of particulate matter, both from combustion and other processes, is endangering their health. Acting as citizen scientists, they will learn about where particulate matter comes from, and how it affects human health. They will also measure particulate matter in their community. The module culminates in a simulated public meeting before a state committee where students will take on different roles to argue whether or not diesel trucks should be banned from traveling through residential neighborhoods.

Module 4: Air and the Chesapeake Bay

Dead Zones, Deposition and Nitrogen Pollution

Anchor phenomenon: Large areas of dead fish floating in the Chesapeake Bay.

The Chesapeake Bay is a natural treasure: it provides innumerable resources and ecosystem services to the living things in its watershed, especially humans. Yet the Bay is also a fragile ecosystem that has been inundated with pollution of all kinds. One of the oft-overlooked sources of pollution to the Bay is air pollution, which contributes a significant amount of nutrient pollution to its waters. In this Meaningful Watershed Educational Experience (MWEE) based module, students start by investigating a fish kill in the Bay, tracing the cause of this phenomenon back to algae blooms and nutrient pollution. Then they continue to work backwards to understand the sources of this nutrient pollution. Along the way they learn about watersheds and airsheds, and collect data on atmospheric deposition. Using this information, they build a model of pollution to the Bay, which they draw upon to create and implement an action plan to combat pollution. As a culmination of their investigation, students present their model and findings to local stakeholders.



Module 5: Air and Climate Change

Rising Temperatures, Rising Tides

Anchor phenomenon: A city that is flooding on a sunny day.

In 2006, former Vice President Al Gore went on tour with the new film "An Inconvenient Truth" to educate Americans about the dangers of climate change. Since then, people in this country and around the world have awakened to the new reality of a warming planet and all the consequences that go with it. In this module, students use the phenomenon of rising sea levels and "sunny day flooding" to investigate the causes and effects of climate change including melting polar ice, the greenhouse effect, atmospheric carbon dioxide levels, and burning fossil fuels. By the end of the unit, students will have developed a cause and effect chain that leads from power plants to flooded coastlines. They will also learn how they can fight climate change through individual action, group effort, and building climate resilience into their communities.

Standards Alignment

The chart below and on the following pages show what middle school standards are taught in each module. Focus standards (F) appear multiple times throughout the module and receive specific instruction. Background standards (B) are utilized less frequently in the module and may not be addressed directly.

For more detailed information about the standards themselves, what aspects of each standard appear in each module, and standards for additional grade levels, see each module's specific standards overview pages.

		Module 1	Module 2	Module 3	Module 4	Module 5
NGSS Science & Engineering Practices	Developing and Using Models	F	F		F	
	Planning and Carrying Out Investigations	B			B	B
	Constructing Explanations	B		B	F	
	Obtaining, Evaluating, and Communicating Information		B			
	Engaging in Argument from Evidence			F		
	Analyzing Data			B		F
	Asking Questions & Defining Problems					B
	Using Mathematics & Computational Thinking					B
NGSS Disciplinary Core Ideas	LS 1.A Structure & Function	F				
	LS 2.A Independent Relationships in Ecosystems	B		B		
	LS 2.C Ecosystem Dynamics, Functioning, and Resilience			B	F	
	ESS 2.D Weather & Climate		B			
	ESS 3.D Global Climate Change					F
	ESS 3.C Human Impacts on Earth Systems		F	F	B	B
	ETS 1.B: Developing Possible Solutions			B		
NGSS Crosscutting Concepts	Systems and System Models	F	B		F	
	Cause & Effect	B		F	F	F
	Patterns		F			B
	Scale, Proportion & Quantity					

NGSS Performance Expectations		Module 1	Module 2	Module 3	Module 4	Module 5
NGSS Performance Expectations	MS-LS 1-3 The body is a system of interacting subsystems	F				
	MS-LS 2-3 Cycling of matter and flow of energy in ecosystems	B				
	MS-LS 2-4 Changes to physical or biological components of an ecosystem affect populations			B	F	
	MS-ESS 3-3 Monitor and minimize a human impact on the environment		B	F		B
	MS-ESS 3-4 Human population and consumption of natural resources impact Earth systems		F			B
	MS-ESS 3-5 Rise in global temperatures					F

		Module 1	Module 2	Module 3	Module 4	Module 5
Virginia Standards of Learning Scientific Practices	6.1 (b) Planning and Carrying Out Investigations	**B**			**B**	
	6.1 (c) Interpreting, Analyzing, and Evaluating Data			**B**		
	6.1 (e) Developing and Using Models	**F**	**F**		**F**	
	6.2 (d) Constructing and Critiquing conclusions and explanations	**B**		**F**	**F**	
Virginia Standards of Learning Science Content	6.7 Air has properties and Earth's atmosphere has structure and is dynamic		**B**			
	6.8 Land and water have roles in watershed systems				**F (a,c,d)**	
	6.9 Human impact on the environment	**F (c)**	**F (c)**	**F (c,e,f)**		
	Earth Science.6 Resource use is complex					**B (a)**
	Earth Science.11 Atmosphere is a complex, dynamic system					**F (d)** **B (c)**
	Earth Science.12 Earth's weather and climate					**F (e)**

		Module 1	Module 2	Module 3	Module 4	Module 5
Common Core State Standards – Literacy	RST.6-8.3: Follow a multistep procedure when carrying out experiments	✓	✓	✓	✓	✓
	RST.6-8.4: Determine the meaning of symbols, terms, words, and phrases in context	✓		✓		✓
	RST.6-8.7: Integrate information from a text with visual information	✓	✓		✓	✓
	WHST.6-8.1: Write arguments focused on discipline-specific content	✓		✓	✓	
	WHST.6-8.1B: Support claims with logical reasoning, data and evidence			✓	✓	
	WHST.6-8.2: Write informative/ explanatory texts					✓
	WHST.6-8.9: Draw evidence from informational texts				✓	
	SL.8.1: Engage in a range of collaborative discussions	✓	✓	✓	✓	✓
	SL.8.4: Present claims and findings			✓	✓	
	SL.8.5: Integrate multimedia and visual displays into presentations				✓	
Common Core State Standards – Math	MP.3: Construct viable arguments and critique the reasoning of others	✓				✓
	6.RP.A.1: Understand the concept of a ratio and use ratio language					
	6.RP.A.3: Use ratio and rate reasoning to solve real world and mathematical problems	✓				✓
	6.SP.B.5: Summarize numerical data sets in relation to their context	✓		✓	✓	✓
	7.RP.A3: Use proportional relationships to solve multistep ratio and percent problems		✓			

Teaching Strategies

On the Air 2020 *employs* a variety of teaching strategies designed to engage students in meaningful scientific work that promotes higher level thinking and communication skills. Sometimes these strategies are described directly in the activity directions. At other times, teachers are tasked with using generic "discussion strategies" or "questioning strategies" from their own repertoires. Below is a sample of teaching strategies that are recommended for use with On the Air 2020.

Discussion Strategies

Science circle (aka Socratic Seminar): Have students arrange their chairs into a circle facing one another to hold a group discussion, for example, to discuss and debate the meaning of the results from an experiment. Encourage students to talk to their peers (as opposed to the teacher) and to engage in meaningful debate and dialogue with one another. The teacher's role is to moderate the discussion, and sometimes to ask questions to the group to provoke further discussion. A variation on the science circle is the **fishbowl discussion,** where one group of students sits on the outside of the discussion circle and listens or observes the discussion circle. Then groups then switch roles partway through the discussion.

Think, pair, share/Turn & Talk: Give students a question or prompt to consider, and then have them turn to a partner to discuss. This partner talk allows all students to participate in the discussion, as opposed to a whole group discussion where many students listen but do not actively contribute. Think, pair, share and turn & talk discussions are often held before a whole group discussion in order to help students clarify their thoughts and hear a different point of view. These types of conversations especially support students with learning disabilities who may be reluctant to participate actively in whole group discussions.

Student-led discussion: Have students engage in a standard whole-group discussion, but have a student lead the discussion instead of the teacher. The student can use common question prompts (ex. "How did you reach that conclusion?", "What evidence do you have to support your claim?" or "Who agrees with what <x> said?"). Alternatively, have the student ask a set of specific questions developed by the student or the teacher in advance. Student-led discussions help promote leadership skills and allow students to learn better questioning techniques of their own. They tend to work best after students have participated in – and analyzed– several discussions led by the teacher.

Silent discussion: Give students a prompt to respond to on paper (ex. Do you think that air pollution is getting better or worse over time?). After they have written a short response, have students pass their papers to someone else in the class. The second student responds to the first students' statement as if they were having a discussion. Papers can then get passed back to the first student, or on to a third student to add to the conversation. After several back-and-forth statements, papers are returned to the original writer to read the full discussion. This discussion technique helps to support students' writing skills, and benefits those students who need additional time to develop their thoughts or who prefer a quieter classroom.

Hand signals: Students use hand signals during a whole-group discussion to indicate to each other and the teacher when they agree with, disagree with, want to link to, want to build on what another student has said, or for other purposes. This technique helps to build equitable classrooms, and works well in a virtual context.

Accountable talk stems: Students use verbal discussion sentence starters to lead safe and respectful conversations with one other. Stems such as, "I agree with…", "I disagree with…", "Can you explain what you mean?" promote meaningful conversations where students feel comfortable sharing without fear of being insulted or intimidated by others. Sentence stems such as, "I heard you say…" and "I like how you…" encourage students to listen to, and paraphrase one other, so conversations build as opposed to jump around.

Sensemaking Strategies

Stop & jot: Students pause to write down thoughts from an activity, observation, or conversation before moving on. Stop and jots can precede a conversation to prepare for talking, or follow a conversation to summarize the discussion.

Discussion: Use any of the discussion techniques described above that promote sensemaking.

Graphic organizers: Venn diagrams, cause and effect charts, flowcharts, and other graphical representations can support sensemaking by providing a structure to students' thinking.

Concept mapping: Have students make their own graphic organizers to show how different concepts are related. These maps can be messy, and often benefit from a few drafts. Concept mapping is often less about the final product and more about the thinking process that goes into creating it.

Modeling: Modeling a scientific concept or process can involve making a graphic organizer or other written description that helps to explain a phenomenon. However, models can also be physical objects, drawings, or even kinesthetic movements that help to clarify or

Analogies and examples: Have students create analogies to help explain a scientific concept. For example, the way transpiration in plants works is similar to sucking water up a straw. You can also have students think of additional examples that exemplify a particular scientific principle. For example, students who are learning about how solids dissolve in liquids might think about sugar in a glass of iced tea, salt in a pot of boiling water, or marshmallows dissolving into a cup of hot cocoa.

Questioning Strategies

Effective questioning strategies guide student sensemaking without taking away the heavy cognitive lifting that students must do for higher-level thinking and real learning. Here are some tips for asking strong questions:

- Ask questions that focus students' attention and require them to think. For example, "How does the graph of temperature relate to the graph of carbon dioxide emissions?"
- Ask open-ended questions that allow students to discuss and debate. For example, "Do these data support or refute your original hypothesis? How?"
- Avoid either/or questions that simplify the thinking too much for students. For example, "Does the graph go up or down?" followed by "Does that mean pollution is getting worse or getting better?"
- Ask questions that require students to back up their answers. For example, "What evidence from your research supports that claim?"

Asking good questions only gets you half way to your goal. Here are some tips for what to do after you've asked your questions:

- Provide adequate wait time after asking questions. Students need time to process questions and think of answers. Do not misinterpret silence as students being "lost." Using turn-and-talks or stop-and-jots (see discussion and sensemaking strategies above) after asking a question are good ways to provide additional processing time.
- Avoid answering your own questions when students don't immediately respond. Just as with providing adequate wait time, students need time to process, and if they learn that you will answer for them, they will stop thinking for themselves.
- Use equity sticks or other "cold-calling" techniques to ensure that you don't find yourself always calling on the same students to answer questions.
- Don't give up on a student if they get stuck or don't get an answer "right." You may let them call on a friend or classmate for support, but remember to return to them to see if they have corrected the previous misconception. This not only shows your confidence in their ability to learn, but it also holds them accountable for staying engaged and fixing any errors.

Rubrics & Feedback Guides

Generic Presentation Rubric

Project area	Beginning	Needs Improvement	Proficient	Advanced
Content	Student's presentation has significant factual inaccuracies and shows limited understanding of the scientific content.	Student's presentation has some factual inaccuracies, and shows some understanding of the scientific content.	Student's presentation is factually accurate, and shows strong understanding of the scientific content.	Student's presentation is factually accurate, and shows detailed and extensive understanding of the scientific content.
Completeness	Student's presentation is missing significant required parts.	Student's presentation addresses most required elements.	Student's presentation addresses all required elements, although some may not be fully complete.	Student's presentation addresses all required elements fully.
Answering questions (if applicable)	Student cannot answer questions about their presentation or answers incorrectly due to gaps in knowledge.	Student can answer some questions about their presentation, but struggles to answer others correctly because of gaps in their knowledge.	Student is able to answer questions about their presentation by drawing upon knowledge from the module, although they may have some gaps in their knowledge.	Student is able to fully answer questions about their presentation by drawing upon knowledge from the module
Craftsmanship	Student's presentation has numerous grammatical errors, and is not delivered smoothly.	Student's presentation has some grammatical errors, and may not be delivered smoothly.	Student's presentation is well-designed, with few grammatical errors. Their presentation may not be delivered smoothly.	Student's presentation is very well designed, with few or no grammatical errors. Their presentation is delivered smoothly and comfortably.

Generic Modeling Rubric

Project area	Beginning	Needs Improvement	Proficient	Advanced
Content	Student's model has significant scientific inaccuracies in depicting relationships or concepts which are not support by (or contrary to) evidence. The model will likely lead to inaccurate explanations or predictions of the phenomenon or modeling scenario.	Student's model has some scientific inaccuracies in depicting relationships or concepts which are not supported by evidence. The model may lead to inaccurate explanations or predictions of the phenomenon or modeling scenario.	Student's model is mostly scientifically accurate, and shows relationships and concepts based on evidence that can be used to explain the phenomenon or modeling scenario and can be used to make reasonable predictions.	Student's model is scientifically accurate, and shows relationships and concepts based on evidence that can be used to explain the phenomenon or modeling scenario and can be used to make reasonable predictions.
Completeness	Student's model has minimal components that are used to describe the phenomenon or modeling scenario.	Student's model is missing important components that are necessary to describe the phenomenon or modeling scenario	Student's model describes most aspects of the complexity and interconnectedness of the different elements that influence the phenomenon or modeling scenario.	Student's model fully describes the complexity and interconnectedness of the different elements that influence the phenomenon or modeling scenario.
Craftsmanship	Student's model is disorganized in a way that prevents others from understanding and interpreting the contents of the model. Errors in spelling in grammar (if present) make the model difficult to understand.	Student's model may be somewhat disorganized in a way that makes it difficult for others to understand and interpret the content of the model. Errors in spelling and grammar (if present) may prevent understanding.	Student's model is organized in a way that it is not difficult for others to understand and interpret the content of the model. Spelling and grammar (if present) are mostly correct.	Student's model is well organized in a way that allows others to easily understand and interpret the content of the model. Spelling and grammar (if present) are correct.

Generic peer feedback form

Feedback from: ______________________ to ______________________

Feedback should be **specific**: what about your partner's work is good or needs improvement?

Feedback should be **helpful**: what suggestion can you make for improvement?

Feedback should be **kind**: use positive and supportive language

Feedback area	**Glows** What was good?	**Grows** What are areas for improvement?
Content Is the information correct and complete?		
Clarity Can you understand what they are trying to communicate?		
Craftsmanship Is the project, presentation, or writing well-made with correct spelling and grammar?		

What questions do you have? ______________________

Differentiation Guide

On the Air 2020 *includes* a variety of differentiation strategies to support learners who have learning disabilities or who struggle with the content for any number of reasons. The strategies below include some of the techniques you will find embedded in the activities themselves, as well as a few additional ideas. Many of these strategies support students of all kinds, regardless of their ability level.

Word banks and vocabulary lists: Word banks and vocabulary lists are helpful whenever students are first learning new vocabulary, but are expected to use that vocabulary as a part of an additional task. For example, if students are expected to build a concept map to summarize their learning from an activity, provide a word list or – better yet – slips of paper with the vocabulary words printed on them for students to arrange into the concept map. This will allow students to engage in the sensemaking task without getting held up by the vocabulary.

Sentence starters: Provide the first few words of a sentence to get students started on the right track when they are writing. These can be especially helpful when students are learning to write Claim-Evidence-Reasoning (CER) arguments so they develop strong habits for these structures.

Small group instruction: When students are assigned a task, pull any students that are struggling into a small group to go over directions or provide additional support. You can also do this in reverse at the end of a mini-lesson. Tell students that they can leave the mini-lesson to begin working independently when they are ready, but to stay and continue for additional instruction if necessary. This can help to alleviate any perceived stigma from being in the "low group."

Provide choices: When students are expected to show what they have learned through a project or presentation, give them choices for how to do it. Some students may prefer to make a poster, while others would rather give a presentation or record a video. Give students the opportunity to showcase their talents and play to their strengths.

Use reading strategies: Many of the readings in On the Air 2020 are in double-entry journal format to support reading comprehension. For other texts, provide strategies and protocols that will help enhance student understanding. For example, have students underline key ideas in a reading and put a question mark by anything they don't understand, or use a graphic organizer to help students organize their thoughts.

Use extensions to challenge advanced students: On the Air 2020 has a variety of built-in extensions for students who finish individual assignments quickly or who would benefit from more challenging work. Rather than make work "harder," provide additional opportunities for students to dig deeper into content, explore related topics of their own interest that will enhance their understanding of the core content, or that will push them to consider more complex viewpoints.

Accessibility Guide

Making science learning equitable for all students is a key component of NGSS-aligned instruction. It is also a part of being an ethical educator. As with differentiation strategies, many of the strategies described below benefit all students, not just those who need the support. Below are some techniques for making sure your instruction is equitable for all the students in your classroom:

Supports for non-native English speakers

- Put up new vocabulary words on word walls and take time to repeat pronunciations and definitions
- Make dictionaries available for students to look up vocabulary words in their native languages. Google translate and other online tools can support this as well. Encourage students to bring in and use other resources they have that can provide assistance
- Teach prefixes, suffixes, and other root word techniques to help students understand where the meaning of specific vocabulary words comes from
- Speak slowly and provide additional processing time for students to understand questions

Supports for students who are new to the area or to the country

- Consider students' diverse cultural backgrounds and experiences when selecting examples or choosing phenomena. Students who grew up in one part of the country can relate well to snowstorms or wildfires, while these phenomena can be totally foreign to others.
- Ask students to share their experiences to enhance the sensemaking process. It is not necessary for the teacher to know everything about where a student comes from, but it is essential to invite students to share their experience.

Supports for students with physical disabilities

- Use technology where possible to support students with physical disabilities that may make it difficult to participate in certain activities. For example, have readings available on a computer or tablet so that the font can be enlarged. Allow students who have difficulty writing to use a computer to answer questions. Turn closed-captioning on in videos for students who are deaf or hard of hearing.
- To support colorblind students, print handouts in high contrast. If students are looking at graphs, charts, or maps that rely on interpreting colors, be sure to point out what parts of the visual are particular colors and/or pair the student with an understanding partner who can provide assistance.
- To support blind or vision-impaired students, provide verbal descriptions of videos or other media that are essential to activities. Make sure that written materials are available in a digital format so that technology can be used for assistance.

Universal Design for Learning (UDL) has additional guidelines and materials for making learning accessible to all. You can find UDL resources here: http://udlguidelines.cast.org/

About Clean Air Partners

Clean Air Partners is a non-profit (501-c3), public-private partnership educating individuals, businesses, and organizations in the greater metropolitan Baltimore-Washington region about health risks associated with poor air quality and the impacts on our environment.

History

For more than 20 years, Clean Air Partners has empowered individuals and organizations to take simple actions to reduce pollution and protect public health. The organization originally started as a joint task force to meet the federal standards under the Clean Air Act. In 1997, a public-private partnership was formed through its founding partners, the Metropolitan Washington Council of Government and the Baltimore Metropolitan Council, officially establishing Clean Air Partners as the local air quality experts in the metropolitan Baltimore-Washington region. Clean Air Partners is administered by the Metropolitan Washington Council of Governments.

Our Team

Consisting of staff, a 31-person Board, and member organizations, Clean Air Partners' team is led by air quality, environmental, and transportation experts on behalf of local businesses and corporations, advocacy and community groups, and government organizations from across the greater metropolitan Baltimore-Washington region.

To learn more about Clean Air Partners and the work the organization does to support clean air throughout the Metropolitan Washington region, visit www.cleanairpartners.net

MODULE 1

Our Lungs, Our Air, Our Health

The Effects of Ozone Pollution on Human Body Systems

Module Overview

The air we breathe provides us with the oxygen we need to survive, but it can also introduce dangerous and harmful chemicals into our lungs and our bodies. In this module, students will take on the role of medical professionals to investigate the phenomenon of an asthma attack. They will begin by studying the structure and function of the human respiratory system, and how it connects to the circulatory system. They will use this understanding to develop a model of how our bodies get and transfer oxygen to our cells. Then they will investigate the effects of ground-level ozone and its role in exacerbating the effects of asthma. They will also have the opportunity to connect this understanding with a common treatment for asthma. Finally, students will demonstrate what they know by using their models to show how air pollution affects the human body.

Anchor phenomenon:

Two students who are having difficulty breathing.

Pacing

- 7 activities + summative assessment
- Approximately 7 class periods + summative assessment

Module Contents

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When to Teach This Module

Finding the right place within a science scope and sequence to investigate air pollution with students can be tricky. Below you will find some information about the module that can help you decide where this it might fit into your own plans for student leaning:

- **Connection to Human Health:** This module focuses on how individuals are affected physiologically by air pollution, in particular from ozone. It ties in very well with student investigations of human body systems, and would work well either integrated into, or at the end of a unit on cell biology. Activities in the unit will have additional relevance for students if they already have some background knowledge of cells, tissues, organs, and organ systems including the structure and function of different parts of living systems.

- **Connection to Earth Science:** Because this module looks at how air pollution affects humans, it would work well as an addition to a unit on the atmosphere, or a unit on human impacts to the environment. In both cases, the unit can provide a personal connection for students to see that air pollution is not just a hazard to the environment, it is potentially harmful to human health as well.

Standards Overview

Middle School NGSS standards alignment

Performance Expectations:

Focus PE: MS-LS1-3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells. [Clarification Statement: Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples could include the interaction of subsystems within a system and the normal functioning of those systems.] [Assessment Boundary: Assessment does not include the mechanism of one body system independent of others. Assessment is limited to the circulatory, excretory, digestive, respiratory, muscular, and nervous systems.]

Background PE: MS-LS2-3. Develop a model to describe the cycling of matter ~~and flow of energy~~ among living and nonliving parts of an ecosystem. [Clarification Statement: Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system.] [Assessment Boundary: Assessment does not include the use of chemical reactions to describe the processes.]

Science & Engineering Practices

Focus SEP: Developing and Using Models
Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

- Develop and/or use a model to predict and/or describe phenomena.
- Develop a model to describe unobservable mechanisms.

Background SEP: Planning and carrying out investigations
Planning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions.

- Conduct an investigation ~~and/or evaluate and/or revise the experimental design~~ to produce data to serve as the basis for evidence that meet the goals of the investigation.
- Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.

Background SEP: Constructing explanations
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- Construct an explanation using models or representations.
- Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.

Disciplinary Core Ideas

Focus DCI: LS1.A: Structure and Function
In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.

Background DCI: LS2.A: Interdependent Relationships in Ecosystems
Organisms, ~~and populations of organisms~~, are dependent on their environmental interactions ~~both with other living things~~ and with nonliving factors.

Crosscutting Concepts

Focus CCC: Systems and System Models – A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

- Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.
- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

Background CCC: Cause and Effect: Mechanism and Explanation – Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

NGSS 5th Grade Standards alignment

Performance Expectations:

5-ESS2-1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. [Clarification Statement: Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere. The geosphere, hydrosphere, atmosphere, and biosphere are each a system.] [Assessment Boundary: Assessment is limited to the interactions of two systems at a time.]

5-LS2-1. Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment. [Clarification Statement: Emphasis is on the idea that matter that is not food (air, water, decomposed materials in soil) is changed by plants into matter that is food. Examples of systems could include organisms, ecosystems, and the Earth.] [Assessment Boundary: Assessment does not include molecular explanations.]

Science & Engineering Practices

Focus SEP: Developing and Using Models
Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.

- Develop and/or use models to describe and/or predict phenomena.

Background SEP: Planning and carrying out investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.
- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.

Background SEP: Constructing explanations
Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.

- Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.
- Identify the evidence that supports particular points in an explanation.

Disciplinary Core Ideas

Focus DCI: LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment. (5-LS2-1)

Crosscutting Concepts

Focus CCC: Systems and System Models – A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

- A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot.
- A system can be described in terms of its components and their interactions.

Background CCC: Cause and Effect: Mechanism and Explanation – Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

- Cause and effect relationships are routinely identified, tested, and used to explain change.

Virginia Standards of Learning (SOLs) alignment

Science & Engineering Practices	
6.1 (e)	Developing and using models. The student will… • use, develop, and revise models to predict and explain phenomena • evaluate limitations of models
6.1 (b)	Planning and carrying out investigations. The student will… • independently and collaboratively plan and conduct observational and experimental investigations; identify variables, constants, and controls where appropriate, and include the safe use of chemicals and equipment • take metric measurements using appropriate tools
6.2 (d)	Constructing and critiquing conclusions and explanations. The student will… • construct explanations that includes qualitative or quantitative relationships between variables • construct scientific explanations based on valid and reliable evidence obtained from sources (including the students' own investigations)
Content Standards	
6th Grade 6.9(c)	6.9 The student will investigate and understand that humans impact the environment and individuals can influence public policy decisions related to energy and the environment. Key ideas include c) major health and safety issues are associated with air and water quality
Life Science LS.2(c)	The student will investigate and understand that all living things are composed of one or more cells that support life processes, as described by the cell theory. Key ideas include c) similarities and differences between plant and animal cells determine how they support life processes

Common Core State Standards alignment

Literacy Standards	
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
RST.6-8.4	Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.
RST.6-8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
WHST.6-8.1	Write arguments focused on discipline-specific content.
SL.8.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.
Math Standards	
MP.3	Construct viable arguments and critique the reasoning of others.
6.RP.A.3	Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations.
6.SP.B.5	Summarize numerical data sets in relation to their context

5E Module Flow

Activity 1 (Engage): Introducing Tatiana & Calvin
Timing: 30-45 minutes
Purpose: Introducing the anchor phenomenon
- ✓ Students will ask questions to build understanding of the phenomenon
- ✓ Students will be able to describe the symptoms related to the phenomenon (asthma)
- ✓ Students will make connections to local asthma health statistics

Activity 2 (Explore): Breathing & Exercise
Timing: 60 minutes
Purpose: Making connections between the respiratory and circulatory systems
- ✓ Students will recognize a connection between breathing and heart rate, especially as related to exercise

Activity 3 (Explain): The Respiratory & Circulatory Systems
Timing: 45 minutes
Purpose: Building understanding of how the respiratory system works
- ✓ Students will know the main parts of the human respiratory system and what they are for
- ✓ Students will know the main parts of the human circulatory system and what they are for
- ✓ Students will know critical facts about the human respiratory system, ex. that oxygen is the gas in the air we need, and carbon dioxide is the gas we need to get rid of

Activity 4 (Explain): Modeling the Respiratory & Circulatory Systems
Timing: 45 minutes
Purpose: Creating a model of the respiratory and circulatory systems
- ✓ Students will create a model to show how the respiratory and circulatory systems connect to each other
- ✓ Students will use their models to explain how oxygen gets from the environment to all the cells of our bodies

Activity 5 (Explore): Seeing Ozone's Effects on Living Things
Timing: 45-60 minutes
Purpose: Understanding how pollution hurts living things
- ✓ Students will make connection between gases in the air (particularly ozone) and damage to delicate parts of living things

Activity 6 (Explain): Air Pollution & Humans

Timing: 30-45 minutes

Purpose: Adding pollution to models of the respiratory and circulatory systems

- ✓ Students will learn additional details about how pollution affects the human body
- ✓ Students will add pollution to their models of the respiratory/circulatory systems

Activity 7 (Elaborate): Asthma & the AQI

Timing: 30-45 minutes

Purpose: Learning how to live safely with asthma

- ✓ Students will learn how to determine if the air quality on a given day is bad
- ✓ Students will learn about how a treatment for asthma (inhaler) works and how to help someone who is having an asthma attack

Activity 8 (Evaluate): Modeling Air Pollution & Human Health

Timing: 30-45 minutes

Purpose: Evaluating student understanding

- ✓ Students will use a model to describe the path that oxygen takes to get to cells.
- ✓ Students will label critical parts of the model.
- ✓ Students will explain the cause & effect relationship between asthma and air pollution using the model

Module Materials

Activity 1 (Engage): Introducing Tatiana & Calvin

- ❒ Handouts: Patient Record (teacher & student versions), KWL chart
- ❒ Materials needed: Projector & speakers, anchor chart paper and markers

Activity 2 (Explore): Breathing & Exercise

- ❒ Handouts: Experiment procedure & data collection sheet, Claim Evidence Reasoning summary
- ❒ Materials needed: thin straws ~¼" diameter (one per pair of students), timer (one per group or one for the whole class)
- ❒ Optional materials: stethoscopes (one per pair of students) and cleaning wipes, graph paper

Activity 3 (Explain): The Respiratory & Circulatory Systems

- ❒ Handouts: Respiratory system diagram (labeled & unlabeled)
- ❒ Materials needed: Computer & projector
- ❒ Optional materials: student computers (recommended), headphones (or speakers) for video, red & blue or purple colored pencils/markers, vacuum cleaner hose

Activity 4 (Explain): Modeling the Respiratory & Circulatory Systems

- ❒ Handouts: N/A
- ❒ Materials needed: student notebooks/paper
- ❒ Optional materials: speaker (for video)

Activity 5 (Explore): Seeing Ozone's Effects on Living Things

- ❒ Handouts: Leaf Investigation lab sheet
- ❒ Materials needed: projector
- ❒ Optional materials: microscopes, ozone-damaged leaves, leaf-mount slide materials (slide, cover slip, dropper, scotch tape), computers

Activity 6 (Explain): Air Pollution & Humans

- ❒ Handouts: Asthma Attacks: Cause & Effect
- ❒ Materials needed: KWL chart (from Activity 1), student models (from Activity 4), projector

Activity 7 (Elaborate): Asthma & the AQI

- ❒ Handouts: Understanding the AQI handout
- ❒ Materials needed: N/A
- ❒ Optional materials: students smartphones (if permitted), projector

Activity 8 (Evaluate): Modeling Air Pollution & Human Health

- ❒ Handouts: Summative assessment, scoring guide
- ❒ Materials needed: N/A

Teacher Background Information

Air Pollution & Exercise
American Lung Association, April 2000

WHO IS VULNERABLE?

Millions of Americans live in areas where the air carries not only life-giving oxygen, but also noxious pollutants that reach unhealthful levels, such as ozone, carbon monoxide, fine particles, sulfur dioxide, nitrogen dioxide, or lead.

Exercise makes us more vulnerable to health damage from these pollutants. We breathe more air during exercise or strenuous work. We draw air more deeply into the lungs. And when we exercise heavily, we breathe mostly through the mouth, by-passing the body's first line of defense against pollution, the nose.

HOW AIR POLLUTION AFFECTS YOUR BODY

Our lungs are among the body's primary points of contact with the outside world. We may drink two liters of liquid each day. We breathe in an estimated 15,000 liters of air, approximately 6 to 10 liters every minute, drawing life-giving oxygen across 600 to 900 square feet of surface area in tiny sacs inside the lung.

Oxygen is necessary for our muscles to function. In fact, the purpose of exercise training is to improve the body's ability to deliver oxygen. As a result, when we exercise, we may increase our intake of air by as much as ten times our level at rest.

An endurance athlete can process as much as twenty times the normal intake. Mouth breathing during exercise by-passes the nasal passages, the body's natural air filter. These facts mean that when we exercise in polluted air, we increase our contact with the pollutants, and increase our vulnerability to health damage.

The interaction between air pollution and exercise is so strong that health scientists typically use exercising volunteers in their research.

MINIMIZE YOUR RISK: MANAGE YOUR EXERCISE

The news isn't all bad. You can minimize your exposure to air pollution by being aware of pollution and by following some simple guidelines: If you live in an area susceptible to air pollution, here's what you should do:

- Do train early in the day or in the evening.
- Do avoid midday or afternoon exercise, and avoid strenuous outdoor work, if possible, when ozone smog or other pollution levels are high.
- Do avoid congested streets and rush hour traffic; pollution levels can be high up to 50 feet from the roadway.
- Do make sure teachers, coaches and recreation officials know about air pollution and act accordingly.
- Most important, do be aware of the quality of the air you breathe!

Don't do the following:

- Don't take air pollution lightly, it can hurt all of us!
- Don't engage in strenuous outdoor activity when local officials issue health warnings.

Source: American Lung Association, Air Pollution & Exercise.

Children & Ozone Air Pollution Fact Sheet
American Lung Association, September 2000

While exposure to ozone air pollution causes adverse health effects in most people, children are especially susceptible to these effects. Children spend significantly more time outdoors, especially in the summertime when ozone levels are the highest.

National statistics show that children spend an average of 50 percent more time outdoors than do adults.

A recent study conducted by the American Lung Association shows that as many as 27.1 million children age 13 and under, and over 1.9 million children with asthma are potentially exposed to unhealthful levels of ozone based on the new 0.08 ppm, eight-hour ozone level standard.

Minority children are disproportionately represented in areas with high ozone levels. Approximately 61.3% of black children, 69.2% of Hispanic children and 67.7% of Asian-American children live in areas that exceed the 0.08 ppm ozone standard, while only 50.8% of white children live in such areas.

Children spend more time engaged in vigorous activity (i.e., exercise). Such activity results in breathing in more air, and therefore more pollution being taken deep into the lungs. A California study found that children spend three times as much time engaged in sports and vigorous activities as adults do.

Children have a higher breathing rate than adults relative to their body weight and lung surface area. This results in a greater dose of pollution delivered to their lungs. Most biological air pollution damage is related to the dose of pollution inhaled in relation to the body weight and surface area of the target organ.

Even when children experience significant drops in lung function, they do not seem to suffer or report some of the acute symptoms, such as coughing, wheezing or shortness of breath, associated with ozone exposure in adults. Thus, children are not likely to receive or may not understand the biological warnings to reduce their ozone exposure by stopping their exercise or moving indoors.

Children have narrower airways than do adults. Thus, irritation or inflammation caused by air pollution that would produce only a slight response in an adult can result in a potentially significant obstruction of the airways in a young child.

During exercise, children, like adults, breathe with both their nose and mouth rather than just their noses. When the nose is by-passed during the breathing process, the filtering effects of the nose are lost, therefore allowing more air pollution to be inhaled.

Air pollution, including ozone, can result in more frequent respiratory infections in children due to impairment of the lung's ability to defend itself. Scientists are concerned that children who experience more frequent lower respiratory infections may be at greater risk of lower-than-normal lung function later in life.

When ozone levels are high, children should avoid calisthenics, soccer, running and other strenuous outdoor exercise. They should be encouraged to participate in less strenuous activities such as recreational swimming, swinging or indoor activities such as floor hockey and gymnastics instead.

Source: American Lung Association.

Additional resources

Asthma:

- General asthma information (source: Mayo Clinic): https://www.mayoclinic.org/diseases-conditions/asthma/symptoms-causes/syc-20369653

Respiratory System:

- Structure and function (source: BBC) https://www.bbc.co.uk/bitesize/guides/z3xq6fr/revision/1

Circulatory System:

- How oxygen is delivered from the lungs to cells in the body (source: CK-12) https://www.ck12.org/c/life-science/breathing/lecture/Gaseous-Exchange/

Air Pollution & Human Health:

- PM2.5 and the Respiratory System: https://www.youtube.com/watch?v=QcS3ovdsgNI

Activity 1 (Engage): Introducing Tatiana & Calvin

ACTIVITY DETAILS

Time: 30-45 minutes

Objectives

- ✓ Students will ask questions to build understanding of the phenomenon
- ✓ Students will be able to describe the symptoms related to the phenomenon (asthma)
- ✓ Students will make connections to local asthma health statistics

Materials

- ✓ Projector & speakers (for video)
- ✓ Anchor chart paper and markers
- ✓ Local asthma data posters

Handouts

- ✓ Patient Record (teacher and student versions)
- ✓ KWL Chart

Teacher Tip

- ✓ If students who have asthma volunteer to play the roles of Tatiana and Calvin, it may make it easier for them to answer questions, but remind them that they are playing a role and should not share their personal health information.

Activity summary: Students are introduced to the anchor phenomenon for the unit: two young people who occasionally have difficulty breathing. They also share background knowledge and develop questions to explore. Finally, they examine local youth asthma statistics to understand the risk asthma poses to their communities.

Standards Connection

SEP: Asking Questions & Defining Problems
CCC: Cause & Effect

Before the activity: One option for the role play portion of this activity is to have 1 or 2 students play Tatiana and Calvin. You will need to identify students who can play these roles in advance and prepare them by giving them the Teacher Guide Patient Records, and explaining to them how to answer students' questions. See the Teacher Tip in the sidebar for additional suggestions about the students.

A second option, if you do not have students who can play Tatiana or Calvin (or you prefer not to do the role play), is to do the warmup and Step 1 of the activity, then show the first part of the video "Between Life & Breath" as an introduction to the patient: https://www.youtube.com/watch?v=OCosTBwG4Pg. Stop the video at 4:30 (before it begins to talk about asthma) and have students chart the symptoms that they see in the video. Then jump ahead to Step 4 of the activity and continue as normal.

A note about role-playing

Students will be excited about taking part in the role play if you are excited and invested in it. Think about ways you can make it more authentic for students. For example, wear scrubs to work (if allowed) and put up signs in the classroom indicating that they are in a medical facility.

Warmup: What questions do doctors ask their patients?

- Possible answers: how are you feeling? What hurts? When does it hurt? etc.
- The purpose of this warmup is to prepare students for the Q&A coming up in step 3 of the activity.

1. **Frame the activity:** Tell students that today they are starting a new investigation where they will act as doctors to help one or two young people who have a common medical problem. In a moment, you will introduce them to the "patients", and the students will have the opportunity to ask them questions about their medical issue. Throughout the investigation, they will use medical thinking to study their patients' problem.

2. **Introduce Tatiana & Calvin:** Pass out the blank "Patient Record" sheet to students and tell them that their first job is to learn what symptoms their patients have. Bring your "patients" up to the front and have them share their names (they should also bring their completed copies of their patient records for reference if they need them). If you have two student volunteers, divide the class into two groups and have each group work with one patient.

3. **Chart symptoms:** Have students fill in the top line of information on their charts. Then have students take turns asking Tatiana/Calvin questions to learn more about what's bothering them. Encourage students to take on the role of doctors as they talk to their patients. Have them think about good follow up questions that a doctor would ask. If they ask Tatiana or Calvin a question they don't know the answer to, have them write down the question on their charts.
   - Symptoms students should uncover: coughing, difficulty breathing, difficulty exercising, wheezing, high heart rate, on some days it's worse than others
   - Students *may* also uncover: they live in a city, near a road that has lots of trucks, they like to play outside, and their symptoms are worse during the summer. If students don't uncover these now, they will have a chance later in the module.

   After students have completed their medical interviews, thank Tatiana and Calvin and have them return to their seats. Have students share what they learned as a whole class, and record the symptoms and information on anchor chart. If there are unanswered questions (unknown answers), write them down as well.

4. **Preliminary diagnosis & KWL Chart.** Ask students to consider what their diagnosis might be. They will likely say that they think Tatiana and Calvin have asthma (if not, you can ask prompting questions to lead them this way). Have them add this preliminary diagnosis to the bottom of their Patient Record sheets. Also ask them what they think might be causing their asthma attacks. Depending on what students know about asthma, they may or may not have ideas about what brings on an asthma attack. Have them add any ideas they have to their preliminary diagnosis.

TEACHER NOTES

Extension

- ✓ If time permits, and you have stethoscopes for Activity 2, you can have students take Tatiana and Calvin's heart rate (in anticipation of the next activity)

Teacher Tip

- ✓ Students with asthma (or who have a close friend or relative with asthma) will likely be engaged with the phenomenon quickly, but others may not be. Use the KWL chart and the local asthma data to help these students to develop curiosity about additional aspects of the phenomenon such as how your lungs work and why certain communities are affected more than others to get them engaged in the module.

TEACHER NOTES

Modifications

- ✓ Have students make their own KWL charts in their notebooks.

Differentiation

- ✓ Create KWL charts with sentence starters or with a few responses already written.

Virginia Asthma Rates

- ✓ Asthma rates in Virginia are below the national average. If you live in Virginia, it may be worthwhile to also share the rates in DC as a way to highlight the problem

Pass out the student KWL charts. On a class KWL chart, write Asthma & Breathing at the top, and have students do the same on their charts. Give students a few minutes to write things on their own charts about what they know and want to know about asthma and breathing. If they are not sure what to write about asthma, remind them that they know some things about breathing, and what might cause someone to have of difficulty breathing. If they don't have things they want to know, push them on whether they know what causes an asthma attack or how your lungs work. Have students share what they know and want to know, and add them to the class chart. Next, have students write things that they would like to learn about Tatiana and Calvin or about asthma and breathing.

Make sure not to provide additional information about asthma to students at this stage of the module. As students develop questions, their curiosity will grow. In the activities ahead, they will develop their own explanations about asthma and their diagnosis.

Sample KWL Chart

Asthma & Breathing		
Know	Want to Know	Learned
Asthma has to do with your lungs People with asthma use an inhaler People with asthma cough a lot People with asthma sometimes can't breathe	Where do you get asthma from? Is asthma contagious? What does an inhaler do? Why is it hard for Tatiana and Calvin to breathe?	

5. **Local asthma data:** Ask students if they think asthma is a problem for kids or other people in their neighborhood (be mindful not to ask students for personal health information, but leave the door open for them to make a personal connection). Tell them that as medical professionals, it is their job to investigate whether conditions like asthma are problems in their communities.

Choose one or more sets of local asthma statistics from the posters below that you think will be most relevant to students. Share them with either by projecting them where all students can see, or putting them up on signs around the room.

Have students read the poster(s) and talk with a partner about how they feel about the statistics. Then have partners share out what they talked about with the class. Use this as an opportunity to point out that asthma is a problem not just for individual patients like Tatiana and Calvin, but also for whole communities. Have students add any additional information from the statistics to their KWL charts in the "Learned" column, and any new questions they have to the "Want to Know" column. Push students to think about why asthma might be worse in some places compared to others.

Tell students that they will come back to this KWL chart throughout the investigation as they learn additional information about asthma.

6. **Formative assessment:** Collect students' KWL charts, or circulate around the room and mark down who has completed their chart. Have students share a question that they are particularly interested in learning the answer to during their investigation.

Air Quality Champion

Dr. Janet Phoenix is an Assistant Research Professor at George Washington University. She also works closely with families in DC to help children with asthma. Read the interview at the end of the module to learn more about Janet and her amazing work.

TEACHER NOTES

Teacher Background Knowledge

- ✓ For an excellent (and disturbing) report on the relationship among poverty, race, location, and asthma in Baltimore, read this article from the Capital News Service: https://cnsmaryland.org/2017/12/04/baltimores-asthma-hot-spot-is-poor-african-american-neighborhood-with-lots-of-empty-houses/

Recommended

- ✓ Have students read the interview with this module's Air Quality Champion to help them understand the people who keep us safe from air pollution and the kinds of work that they do.

STUDENT HANDOUT

Patient Record

Today's Date	**Doctor's Name**
Patient Name	
Age	**Height**
Heart symptoms	
Respiratory symptoms	
Digestive symptoms	
Additional information (ex. other aches and pains, home/neighborhood information, exposure to chemicals or other hazards, etc.)	
Medications taken	
Preliminary Diagnosis	

TEACHER GUIDE

Patient Record

Today's Date	**Doctor's Name**
Patient Name Tatiana Eliza	
Age	**Height**
Heart symptoms • Heart races sometimes, especially when running	
Respiratory symptoms • Gets very hard to breathe sometimes • Coughing • Can't talk when it's hard to breathe	
Digestive symptoms • none	
Additional information (ex. other aches and pains, home/neighborhood information, exposure to chemicals or other hazards, etc.) • Tightness in chest • Lives in the city near a road that has a lot of trucks • Symptoms are worse in the summer	
Medications taken • none	
Preliminary Diagnosis • Asthma attack	

TEACHER GUIDE

Patient Record

Today's Date	**Doctor's Name**
Patient Name Calvin Robertson	
Age	**Height**

Heart symptoms

- High heart rate when he has a hard time breathing

Respiratory symptoms

- Gets very hard to breathe sometimes
- Coughing
- Wheezing

Digestive symptoms

- none

Additional information (ex. other aches and pains, home/neighborhood information, exposure to chemicals or other hazards, etc.)

- Lives in the city near a big highway
- Likes to play outside
- Symptoms are worse in the summer

Medications taken

- Uses an inhaler

Preliminary Diagnosis

- Asthma attack

STUDENT HANDOUT

Name ______________________________

Know	Want to Know	Learned

CLASSROOM POSTER

Washington, D.C. Asthma Statistics

- 31% of teenagers in D.C. have asthma compared to 21% nationally

- Students of color in DC are far more likely to have asthma than white students

Black = 32.1%
American Indian = 33.6%
Hispanic = 28.8%
White = 20.5%

Source: DC Health Matters: https://www.dchealthmatters.org/indicators?keywords=asthma

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Virginia Asthma Statistics

- 6% of Virginia students visited an ER or urgent care because of asthma in 2013.

- 6.9% of children under 17 in Virginia had asthma in 2016, which is below the national average of 7.5%

Source: Virginia Department of Health: https://www.vdh.virginia.gov/asthma/asthma-infographic/; https://www.vdh.virginia.gov/content/uploads/sites/94/2018/11/Asthma-Burden-Report_Final_102320181.pdf

CLASSROOM POSTER

Baltimore, MD Asthma Statistics

- 28% of high school students in Baltimore City reported having been diagnosed with asthma in their lifetime, compared to 20% of students nationwide in 2007.
- 20% of Baltimore City children under 18 have asthma, which is more than twice the national average (9.4%)
- Baltimore's pediatric asthma hospitalization rate is the highest in Maryland and one of the highest in the nation.

Source: Baltimore City Health Department
https://health.baltimorecity.gov/node/454#:~:text=%20Baltimore%20City%20children%20under%2018,%E2%80%8Bthe%20highest%20in%20the%20nation.

Maryland Asthma Statistics

- Lifetime asthma prevalence in Maryland children showed an increase of approximately 54.7% from 2001 to 2010.
- The child lifetime asthma prevalence is significantly higher in Maryland vs. the United States (16.4% vs. 12.6%).

Source: Maryland Department of Health and Mental Hygiene
https://phpa.health.maryland.gov/mch/Documents/Asthma%20in%20Maryland%202012.pdf

CLASSROOM POSTER

National Asthma Statistics

- Asthma accounts for the greatest loss of productivity either through missed work days or school absenteeism.

- Nationally, it is estimated that 10 million work days and almost 14 million school days are missed each year due to asthma.

- About 6 million children (1 in 12) ages 0-17 have asthma.

Sources: Baltimore City Health Department: https://health.baltimorecity.gov/news/blog-post/2015-05-14-let%E2%80%99s-talk-about-how-b%E2%80%99more-asthma-aware#:~:text=Asthma%20accounts%20for%20the%20greatest,each%20year%20due%20to%20asthma.
US Centers for Disease Control & Prevention: https://www.cdc.gov/vitalsigns/childhood-asthma/index.html#:~:text=1%20in%2012.,to%20about%205%25%20in%202013.

Activity 2 (Explore): Breathing & Exercise

Activity summary: In this activity, students investigate the connection between the respiratory system and circulatory system by doing a set of experiments involving measuring heart rate and breathing.

Standards Connection
DCI: LS 1.A: Structure & Function
SEP: Planning & Carrying Out Investigations
CCC: Cause & Effect

Warmup: When have you gotten out of breath before?

- Students may say things like: when they exercise, when they climb a lot of stairs, when they're tired, etc.
- This warmup is designed to help students begin to make a connection with the experience of having an asthma attack

1. **Frame the activity:** Tell students that you are going to look back at some of the questions they created during our last activity. Use the KWL chart to bring up questions such as:
   - Why is it hard for Tatiana and Calvin to exercise?
   - Why do you get out of breath?
   - What happens to your body when you exercise?

   While it is impractical to have students design this whole experiment from scratch, they likely have ideas about how they could use experiments to answer these questions. Use the strategies below to help them refine these ideas:
   - Ask students how they could possibly test how your body reacts to exercise. If they suggest doing exercises, ask what kind of exercise they could do in a classroom. Write down these answers on the board to save for Test 2 & Test 4.
   - Ask what kinds of measurements they could take to see how your body reacts to exercise and asthma. They will likely include heart rate, and possibly breathing in some way.
   - Ask how they could simulate what it's like to have asthma. They may not suggest using a straw to limit air intake, but they may have some equally interesting suggestions.

   While students respond to your prompts, use follow up questioning to help guide their thinking (ex. what data can you collect about breathing?). You will likely be able to help them come up with ideas that match or are similar to the tests you have planned.

ACTIVITY DETAILS

Time: 60 minutes

Objectives

- ✓ Students will make a connection between breathing and heart rate, especially as related to exercise
- ✓ Students will recognize that shortness of breath can make it hard to exercise

Materials

- ✓ Thin straws (diameter approx. ¼ inch) – cut in half
- ✓ Timer (one per group or one for whole class)
- ✓ Stethoscope (optional) and cleaning wipes/alcohol

Handouts

- ✓ Experimental procedure and data collection sheet
- ✓ Claim-Evidence-Reasoning Summary

TEACHER NOTES

Differentiation & Accessibility

- ✓ Choose partners carefully so that students with needs (physical and/or cognitive) can support one another

Safety tips

- ✓ Wipe down stethoscopes with alcohol wipes after using
- ✓ Monitor students for any signs of difficulty breathing, especially during Test 4, to ensure their safety.

Modifications

- ✓ If you only have one timer, use a class timer on the projector or use a watch, and have all groups start and stop at the same time for both the breathing and the 30 seconds afterwards.
- ✓ If student computers are available, have students record their data in a Google spreadsheet to more easily share later on.

After students have had a chance to share their experiment ideas, tell them that they are going to do a set of experiments today like the ones they suggested. The experiments will help to answer some of these questions they had about Tatiana and Calvin by measuring their heart rate and their breathing. These are two ways to see how our body reacts to something like exercise.

2. **Introduce the experiment.** Start by sharing the main details of the experiments with students: they will be working in pairs to conduct four different tests using two different variables: resting or exercising and breathing normally or breathing through a straw (to simulate having asthma). Because there are two different variables they are testing, there are four different combinations. You may want to show them this chart or make one of your own to show the different tests.

	Resting	Exercising
Breathing normally	**Resting Breathing normally**	**Exercising Breathing normally**
Breathing through straw	**Resting Breathing through straw**	**Exercising Breathing through straw**

One student in each pair will be the participant, and the other will be the data collector. For each test, the participant will do the test while the data collector counts breaths, and measures heart rate afterwards. Assign student partners, and hand out the experiment procedure and data collection sheets.

NOTE: Breathing through a straw and exercising can be physically challenging for students. Students who have respiratory issues such as asthma should be the data collector for this experiment.

Students should not have a problem counting their breaths, but they may need practice measuring heart rate. If you have stethoscopes to use, this will make it easier. If not, have partners wrap their whole hand lightly around their partners' wrist. They should be able to feel a heartbeat. It may be helpful to do a practice round of data collection with students before starting the experiment.

3. **Test 1 (resting, no straw).** Hand out any additional materials such as stopwatches. Then review steps 1-3 of the procedure with students. When all students are ready to start, begin testing. Monitor students and support as necessary.

4. **Test 2 (exercise, no straw).** For this test, you will need to decide as a class what the "exercise" will be. Use suggestions from the framing part of the activity as a starting point. The exercise can be jumping jacks, jogging in place or any moderately strenuous exercise. Consider the capability of students in the class and any disabilities when choosing. Remind students that they will need to count breaths while doing the exercise so it shouldn't be overly complicated. Review steps 4-5 with students, then monitor and support as necessary.

5. **Pool data & review**. Have the class pool their data for Tests 1 & 2 either by writing it on the board, or by using a spreadsheet that is projected. Calculate averages for breathing and heart beats for each test and have students record the class data on the "Summary of Class Data" page of their data sheet. Have students answer the first two questions at the bottom of the sheet (When was heart rate fastest? When did they take the most breaths?) and review together as a group. If possible (based on the data), help students make a connection back to the opening questions: ex. when you exercise, your body takes more breaths and your heart beats faster.

6. **Test 3 (resting, with straw)**. Hand out straws to Partner As. Ask students what they might be trying to understand by using the straws (i.e., understanding what happens to your body when you don't get as much air). Review steps 6-7 with students, then monitor and support as necessary while they conduct the test. Be sure to remind students that they should only breathe through the straw (not their nose)

7. **Test 4 (exercising, with straw).** Review steps 8-9 with students, then monitor and support as necessary while they conduct the test. This test may be strenuous for students, so tell them that they can slow down their exercise if necessary, and they can stop if they don't feel well. Student safety is a priority.

8. **Pool data & review.** Have the class pool their data for Tests 3 & 4 the same way they did with Tests 1 & 2. Calculate averages and have students write them on their data sheets. Then have them answer the rest of the questions below with their partners. Students will likely see that they have higher heart rates and take more breaths when they exercise vs. not exercising, and they have higher heart rates and take more breaths when breathing through a straw vs. not. The highest heart rates and breathing will likely be while exercising and breathing through a straw. After students

TEACHER NOTES

Modification

- ✓ Before having students pool data with the whole class, have each pair get together with another pair to compare their data. Is it similar or different? Have them think about why it might be similar or different.

Graphing

- ✓ This experiment does not require a lot of complex data analysis that requires graphing, but it is a good opportunity for students to practice graphing their own data. If you would like, have students create bar graphs of their data (or the class data) from their four experiments to help with the analysis.

TEACHER NOTES

Extension

- ✓ If time permits, have students discuss other variables they could test to build further understanding what makes asthma worse (does temperature matter? Does being inside or outside matter? etc.) Even if students don't have time to do the tests, it will help build their scientific investigation skills.

Modification

- ✓ If the Claim-Evidence-Reasoning (CER) structure is new to students, this would be a good time to go over the structure and write this CER together as a class. You can also provide one or two of the pieces and have students write the other parts.

have answered the questions, lead a short discussion to summarize the results.

9. **Class discussion.** Return to the questions you considered at the beginning of class (ex. Why do Tatiana and Calvin have a hard time running or exercising?) Lead students through a group discussion to strengthen their understanding of the answers to these questions. Some key takeaways are:
   - **Your breathing rate goes up when you exercise because your body needs more air (oxygen).** Students may or may not know that they need the oxygen to get energy from the food they eat, but you can mention that the human body uses this oxygen to get energy for everything it does.
   - **Your heart rate increases when you get less air and when you exercise.** Students may know that your heart helps to deliver air (oxygen) to your body by pumping your blood which is carrying the oxygen, so when you have less air, you need to deliver it faster. If not, they will learn more about the connection between oxygen and how your body gets it in the next activity.

10. **Return to the KWL chart:** Have students take out the KWL charts they created in Activity 1 and display the class KWL chart you made. Have students identify anything new they've learned that helps them to understand the phenomenon. For example: your heart rate and your breathing rate are connected. Add any new learning to your chart while they add it to theirs.

11. **Formative assessment.** Hand out the Claim Evidence Reasoning (CER) summary sheet for students. Have them use the CER structure to write an answer to one of the questions using their data. You may want to choose which question they will answer (you can also choose another one). A possible CER response to the question: "Why is it hard for Tatiana and Calvin to exercise?" could be:
    - Claim: It is hard for Tatiana and Calvin to exercise because when you exercise your body needs more air and they can't get enough air because they can't breathe well (like the small straw).
    - Evidence: Our breathing rates were higher in Test 2 & 4 when we were exercising. It was hardest to exercise in Test 4 when we had to use the straw.
    - Reasoning: Your body needs air to exercise, and if you can't get enough air because you have trouble breathing, then it makes it hard to exercise.

Name ______________________________

STUDENT HANDOUT

Experiment Procedure: Exercise & Breathing

Materials:

- Small straw (one for each person participating)
- Timer
- Stethoscope (optional) with cleaning wipes
- Data sheet

Procedure:

1. Decide which partner in your group will be participating in the experiment (A) and which partner will be collecting the data (B). Partner A will be performing the tests, while Partner B collects information from Partner A. Write your names on your data sheet.

Test 1: Resting. No Straw

2. Find the place on your data sheet that says "Test 1." You will write down your data for the first part of the experiment here.

3. For this test, Partner A will breathe normally. While they are breathing, both partners should count the number of breaths they take in 30 seconds. Partner B will use the timer to keep track of the time. **As soon as 30 seconds is finished**, record the number of breaths and start counting heartbeats for Partner A using a stethoscope or holding your partner's wrist. Begin the test when you are ready.

Test 2: Exercising, No Straw

4. Find the place on your data sheet that says "Test 2." You will write down all your data for this part of the experiment here.

5. This test is the same as Test 1, except this time Partner A will exercise using the method chosen by the class. Like the other tests, count breaths for 30 seconds during the test, and count heartbeats for 30 seconds after the test. Record your data as soon as you are finished.

Test 3: Resting, With Straw

6. Find the place on your data sheet that says "Test 3." You will write down all your data for this part of the experiment here.

7. This test is the same as Test 1, except this time Partner A will breathe through a straw. Partner A should make sure to only breathe through the straw and not their nose. Like the last test, count breaths for 30 seconds during the test, and count heartbeats for 30 seconds after the test. Record your data as soon as you are finished.

Test 4: Exercising, With Straw

8. Find the place on your data sheet that says "Test 4." You will write down all your data for this part of the experiment here.

9. This test is the same as Test 3, except this time Partner A will exercise. Like the other tests, count breaths for 30 seconds during the test, and count heartbeats for 30 seconds after the test. Record your data as soon as you are finished.

STUDENT HANDOUT

Data Sheet: Exercise & Breathing

Partner A Name: ______________________________

Partner B Name: ______________________________

No Straw

	Breaths in 30 seconds	Heart beats in 30 seconds
Resting	Test 1	Test 1
Exercising	Test 2	Test 2

With Straw

	Breaths in 30 seconds	Heart beats in 30 seconds
Resting	Test 3	Test 3
Exercising	Test 4	Test 4

Summary of Class Data

No Straw – Class Averages

	Breaths in 30 seconds	Heart beats in 30 seconds
Resting	Test 1	Test 1
Exercising	Test 2	Test 2

With Straw – Class Averages

	Breaths in 30 seconds	Heart beats in 30 seconds
Resting	Test 3	Test 3
Exercising	Test 4	Test 4

Compare your data for tests 1 with test 2 (resting vs. exercise). When was Partner As heart rate the fastest? ______________________________

When did Partner A take the most breaths? ______________________________

Compare your data for test 3 with test 4 (resting vs. exercise). When was Partner As heart rate the fastest? ______________________________

When did Partner A take the most breaths? ______________________________

Compare your data for test 1 with test 3 (straw vs. no straw). When was Partner As heart rate the fastest? ______________________________

When did Partner A take the most breaths? ______________________________

Compare your data for test 2 with test 4 (straw vs. no straw). When was Partner As heart rate the fastest? ______________________________

When did Partner A take the most breaths? ______________________________

Name________________________________

STUDENT HANDOUT

Claim-Evidence-Reasoning

Use the data from your experiments today to write a Claim-Evidence-Reasoning argument to answer one of the questions below:

- Why is it hard for Tatiana and Calvin to exercise?
- Why do people get out of breath?
- What happens to your body when you exercise?

Your claim should answer the question. Your evidence should come from your experiment data, and your reasoning should be based on what you know about how the human body works.

Claim:

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____

____

Evidence:

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____

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____

____

Reasoning:

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____

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____

____

Activity 3 (Explain): The Respiratory & Circulatory Systems

ACTIVITY DETAILS

Time: 45 minutes

Objectives

- ✓ Students will know the main parts of the human respiratory system and what they are for
- ✓ Students will know the main parts of the human circulatory system and what they are for
- ✓ Students will know critical facts about the human respiratory system, ex. that oxygen is the gas in the air we need, and carbon dioxide is the gas we need to get rid of

Materials

- ✓ Computer & Projector
- ✓ Student computers (recommended)
- ✓ Headphones for students (for video) or speakers
- ✓ Red & blue (or purple) colored pencils or markers (optional)
- ✓ Vacuum cleaner hose (optional)

Handouts

- ✓ Respiratory and Circulatory Systems (diagram and graphic organizer) w/ teacher guide

Activity summary: In this activity, students use an online simulation to build background knowledge of how the respiratory and circulatory systems interact. They then use this information to compare and contrast the two systems using a Venn diagram.

Standards Connection

DCI: LS 1.A: Structure & Function
CCC: Systems & System Models

Warmup: Why do we need to breathe?

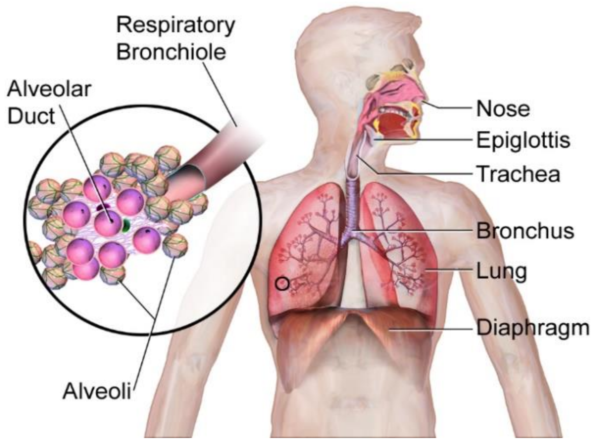
- This seemingly simply question can have answers that range from the basic ("to get air") to the complex ("to bring in oxygen that our cells need to get energy from food and remove carbon dioxide that our cells need to get rid of). The goal of this warmup is to activate students' background knowledge and get a survey of what they already know before the activity.

1. **Frame the activity:** Tell students that understanding what is happening to Tatiana and Calvin means we need to understand what's happening when air goes into their bodies. In this activity, they will build that understanding by learning more about human body systems.

2. **Charting background knowledge.** Use the warmup to hold a short discussion with students about what they already know about the respiratory system. Add these details to the class KWL chart they made in Activity 1 (and their individual charts if they have them). Students may already know things like "lungs are in the respiratory system" and "you breath oxygen and breathe out carbon dioxide." Limit the chart to what students already know. Be sure to use questions to determine students' understanding of the idea that the respiratory system is made of individual organs such as the lungs and trachea, and why it is called a "system" (because it is made of parts (organs) that work together).

3. **Organs of the respiratory system.** Hand out the Respiratory and Circulatory Systems sheet to students. Display the diagram of the respiratory system (below) where all students can see it, and go over the organs. If students already know some organs, start with the ones they know. Have students label their own diagrams as you go. NOTE: Some parts of the system have been left labeled because they are less critical for students to

memorize. Use the organ/organ system language when describing the parts to help students internalize the "organs make up an organ system" concept.



Source: https://upload.wikimedia.org/wikipedia/commons/e/e7/Respiratory_System_%28Illustration%29.png

4. **Lung attack simulation.** Have students take out their KWL charts from Activity 1, and tell them that they are going to use a simulation to learn more about how humans breathe. As they watch the simulation, they should add things they learned to the "Learned" section of their KWL chart (if they run out of room they can start on the back or get another KWL chart). Pass out student computers (if available) and have them complete the "Normal Breathing" section of the Lung Attack simulation found here: http://web1.pima.gov/deq/lungattack/lungplay.htm. If student computers are not available, you can run the simulation together using a projector.

   After students have completed the simulation, have them turn to a partner to compare what they learned and add anything they are missing to their charts. Then have the whole class share out what they learned, and add this information to the class KWL chart. One critical point to highlight is the fact that the respiratory system is the only way for humans to get oxygen into our bodies that our cells need to function. Key takeaways:
   - Oxygen is the gas in the air our body needs
   - Our whole bodies need oxygen
   - We get oxygen into our bodies through our lungs
   - Alveoli are the part of our lungs where oxygen gets into our blood and carbon dioxide comes out
   - Hemoglobin carries oxygen around our bodies

TEACHER NOTES

Teacher Tip

- ✓ Students should be able to use appropriate scientific terminology when talking about the respiratory system, but don't get bogged down in having students memorize a list of individual organs. This module focuses on the big concepts of human health and air pollution and should not feel like an anatomy lesson.
- ✓ A vacuum cleaner hose is a great way to show students what the trachea is like. It is flexible and rigid at the same time to allow air to flow even when you move your body around, yet it doesn't collapse when pressed on because of rings of cartilage that give it structure.

Differentiation

- ✓ Provide pre-filled copies of the respiratory system diagram to students (but still discuss the parts with them)

TEACHER NOTES

Connection to Activity 2

- ✓ Ask students what they were feeling when they were measuring heart rate in Activity 2 (the pressure from heart beats on their chest or through their blood vessels)

Organs of the circulatory system?

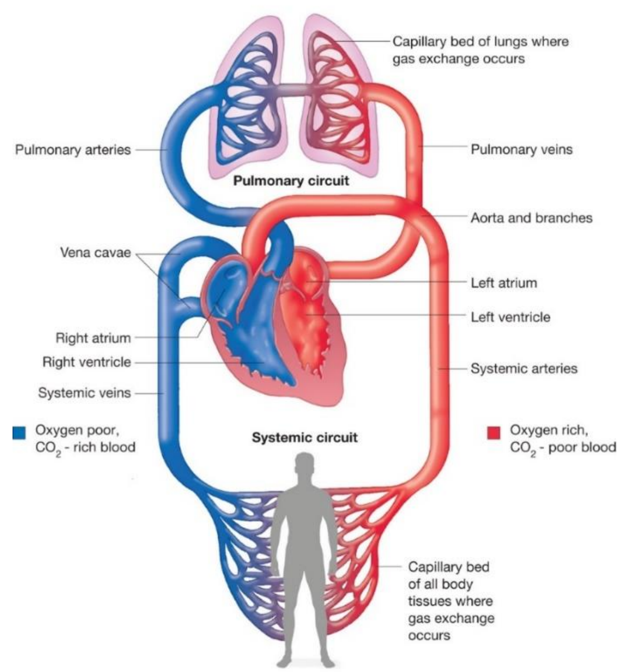
- ✓ Blood vessels such as arteries, veins, and capillaries are sometimes considered organs of the circulatory system, mainly because like other organs they are made of different kinds of tissues and serve a distinct function. However, since they are so different from other human organs, they are frequently not identified specifically this way. If students ask, you can ask them what they think, and then provide this information to support their understanding.

Differentiation

- ✓ Have students complete the Venn diagram with a partner instead of on their own.

5. **How the circulatory system works:** Ask students what happens to oxygen once it gets into our blood. They should remember from Lung Attack that it gets delivered throughout our bodies. Direct students' attention to the circulatory system diagram on the right side of their handouts. Tell students that to understand more about how this works, they're going to watch a video called "Exploring the Heart." Have students go to the video here (or show it using the projector): https://www.youtube.com/watch?v=-s5iCoCaofc, and have them follow along on their diagrams as they trace the path of a red blood cell.

   After the video, have students add arrows to their diagrams showing the flow of blood through the circulatory system. If colored pencils or markers are available, have students color in the key to the diagram (red is oxygen-rich/CO_2-poor blood, blue or purple is oxygen-poor, CO_2-rich blood) and color in the blood vessels in their diagram. You may want to do this together or display a color version of the diagram to help students draw the arrows and color the diagram correctly. Also be sure to ask students what the primary organ of the circulatory system is (the heart) to reinforce the organ/organ system idea.

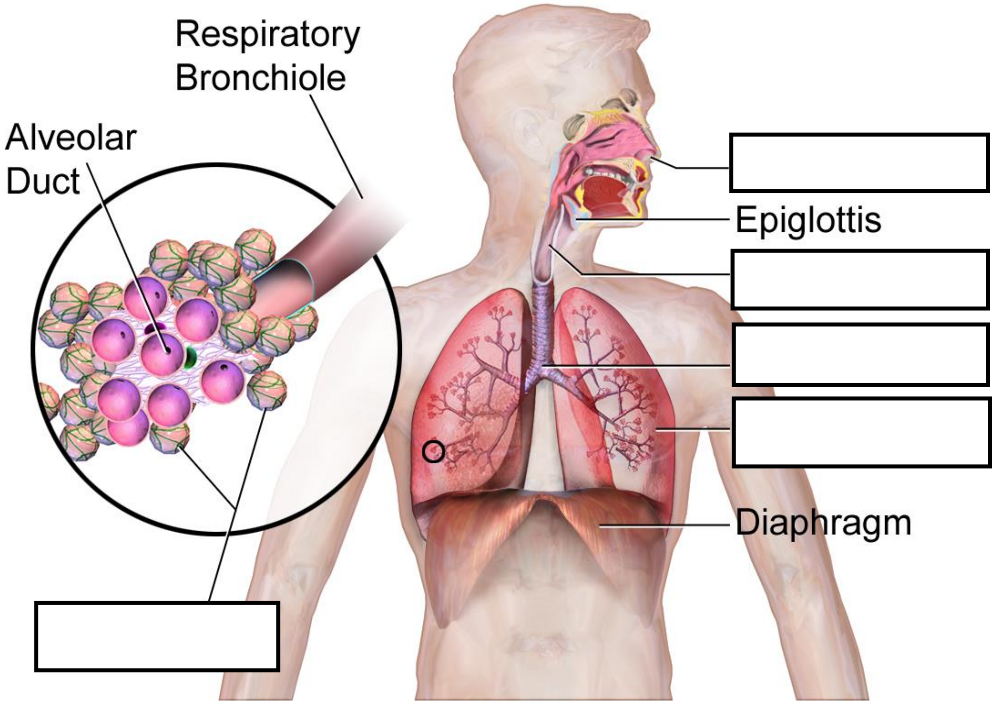


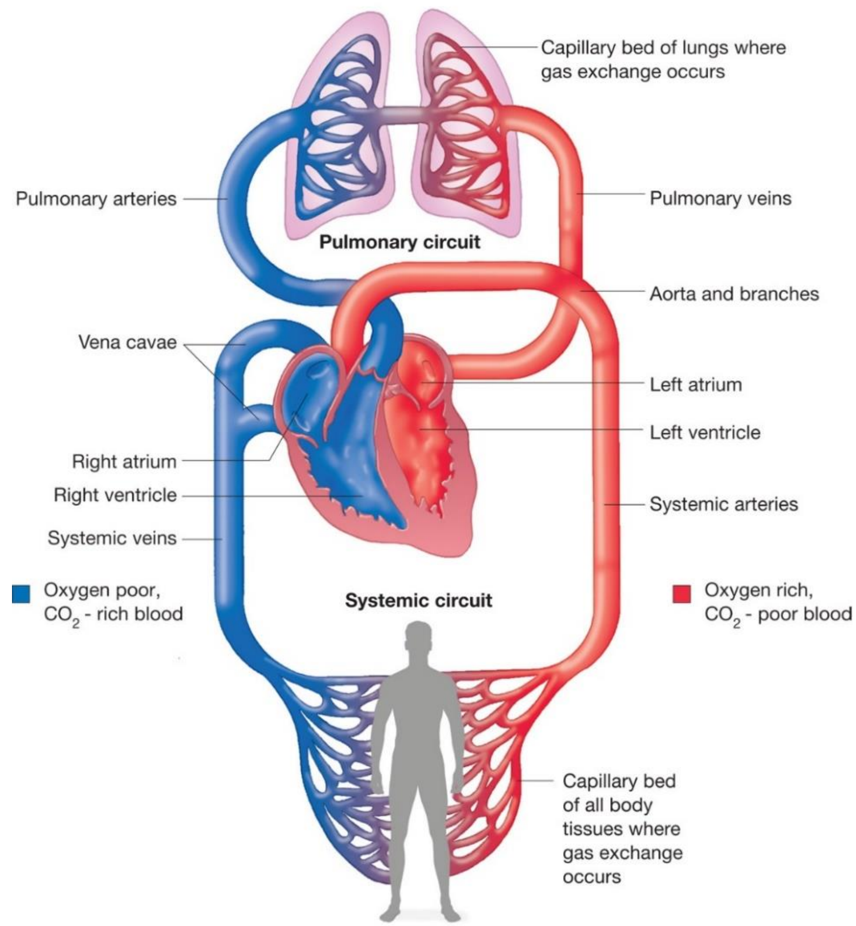
6. **Formative Assessment**: Have students complete the Venn diagram showing similarities and differences between the respiratory system and the circulatory system. You may want to give them a few hints to get them started. Check to see if students have the key points identified in the teacher guide. The "other important information" section can include other facts they've learned.

Name ______________________________

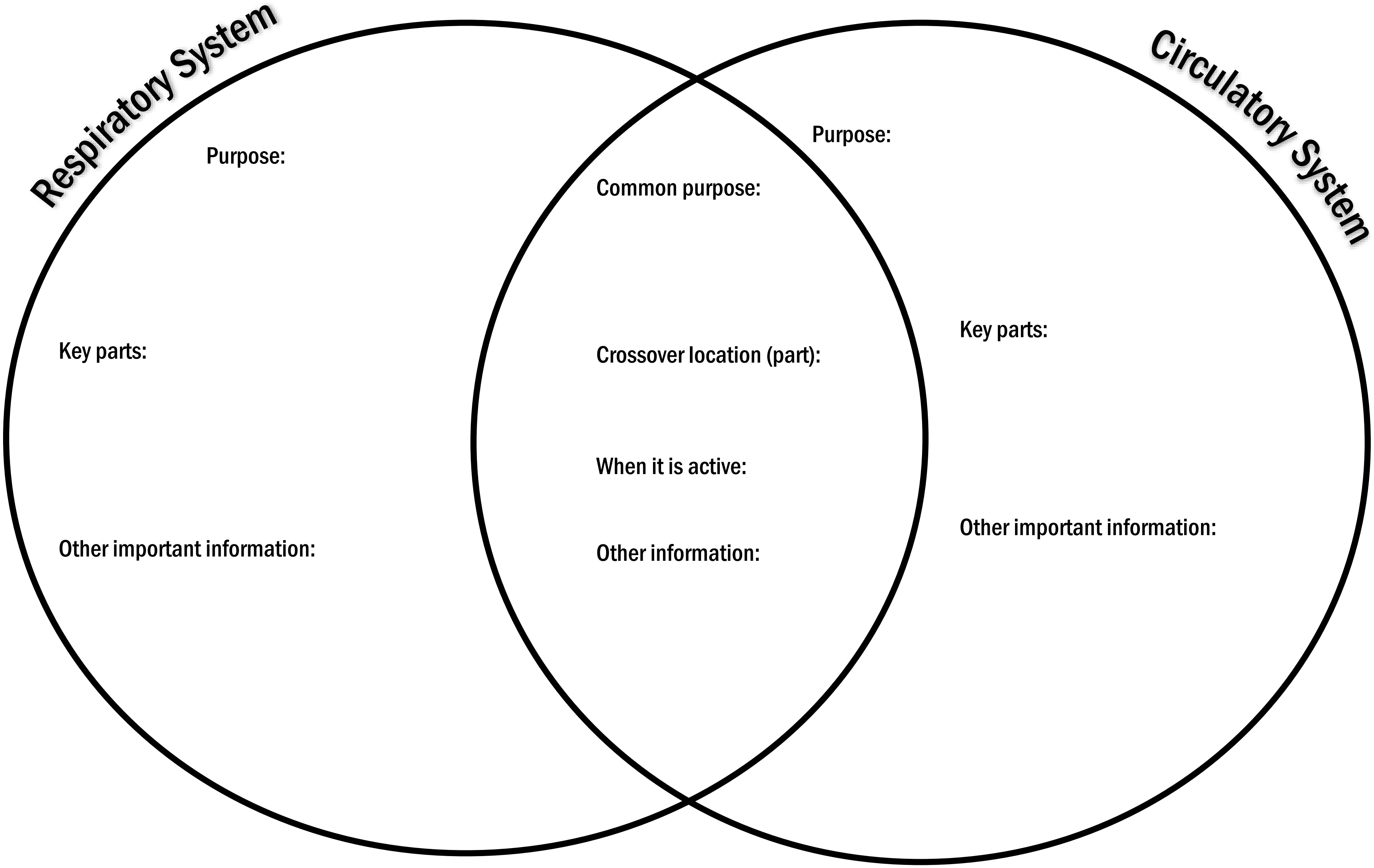
STUDENT HANDOUT

Respiratory & Circulatory Systems





Compare & Contrast



TEACHER GUIDE

Compare & Contrast

Respiratory System

Purpose: Get oxygen into the lungs and carbon dioxide out of the lungs

Key parts: nose & mouth, trachea, bronchi, lungs, alveoli

Other important information:

Both

Common purpose: Deliver oxygen and carbon dioxide

Crossover location: Alveoli

When it is active: all the time

Other information: Both are organ systems

Circulatory System

Purpose: Deliver things throughout the body

Key parts: heart, veins, arteries, blood vessels, red blood cells

Other important information:

Activity 4 (Explain): Modeling the Respiratory & Circulatory Systems

ACTIVITY DETAILS

Time: 45 minutes

Objectives

- ✓ Students will create a model to show how the respiratory and circulatory systems connect to each other
- ✓ Students will use their models to explain how oxygen gets to the different parts of our bodies

Materials

- ✓ Computer & projector
- ✓ Speakers (optional for video)
- ✓ Paper for student models
- ✓ Respiratory/Circulatory System Model (sample)

Handouts

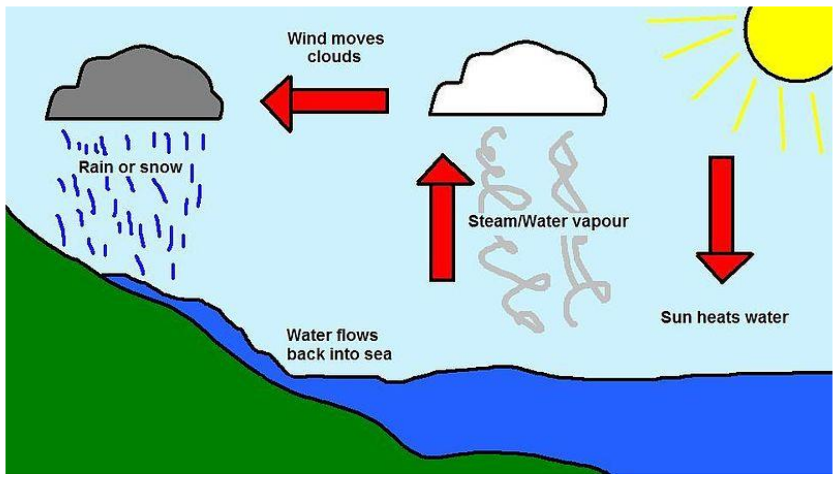
- ✓ None

Activity summary: In this activity, students use what they have learned so far in the module to create a model showing how the respiratory and circulatory systems interact.

Standards Connection

DCI: LS 1.A: Structure & Function
SEP: Developing & Using Models
CCC: Systems & System Models

Warmup: Show students a simple scientific model like the water cycle model below:



Have students write down the answers to these three questions.

- What kinds of things do you see in this model?
- In what way does this model look realistic?
- In what way does this model not look realistic?

Go over the first question, and write students responses on the board. Make sure students mention the arrows, words, and objects. Afterwards, tell students that you will come back to these in a few minutes. Then go over questions two and three.

- The purpose of this warmup is for students to recognize that scientific models often include things like words, arrows, and simplified drawings of real-world things. Scientific models are often not physical, and they are used to explain phenomena like rain and clouds. They often do not look realistic, and can be very abstract.

1. **Frame the activity:** Tell students that when scientists are studying very complicated systems, like the human body, they use models to make the system easier to understand. We're going to create models today based upon everything we've learned so far. We'll use our models to help understand how oxygen gets to our bodies through the respiratory and circulatory systems. Hopefully this will help us to figure out what's happening with Tatiana and Calvin.

2. **Identify the respiratory system parts of the model:** On the board/chart paper, write: "Respiratory System" Ask students what they think needs to be in their models. They should use their notes from the previous activity and ideas from their warmup to help. Add their responses to the list.
   - Nose, lungs, bronchi, trachea, alveoli, air/oxygen, carbon dioxide

3. **Modeling the respiratory system:** Have students (on their own or in small groups), create a simple model of the respiratory system. Remind them that models don't need to look like the actual real-world objects. For example, they can draw a box and write "lungs" on it. They can use the two lists on the board to help them (parts of models and respiratory system). As students work, circulate and support as needed. You can use the sample Respiratory-Circulatory System Model at the end of the activity as a guide, but make sure students are all making their own models. Modeling is a valuable part of the sensemaking process, so student models will be similar, but will likely look different.

   When students have gotten their models to a point where they make sense, have them partner with another student (or another group) to share and explain their models. This provides the benefit of giving students a chance to practice explaining their models, and also to get ideas from their classmates. You may also want to show one model to the class and have students give "warm and cool" feedback to help highlight strong points and improve weak points in the model. This is a great way to help students improve their modeling and peer feedback skills. Afterwards, give students time to revise their models if they want.

4. **Identify the circulatory system parts of the model:** Write "circulatory system" on the board and add student responses. Make sure they include:
   - Heart, arteries, veins, blood, blood vessels

   They may also choose to include things like red blood cells or capillaries, but they should avoid getting into too many details like valves.

TEACHER NOTES

Mini-lesson

- ✓ If students have not created scientific models before, it is worth taking time to discuss the difference between a scientific model and a traditional model. See this website for more info on how to teach modeling to students: https://edu.rsc.org/feature/how-to-teach-scientific-models/3010560.article

Differentiation

- ✓ Instead of having students make their own models from scratch, put components of the model on small slips of paper (words, arrows, boxes), and have students create the model using the parts and glue/tape it onto a sheet of paper or into their notebooks
- ✓ Create a handout with boxes for body, respiratory system, and circulatory system, and have students fill in the rest of the model

TEACHER NOTES

NGSS connection

- ✓ The concept that the human body is a system of interacting subsystems is a key component of this module's focus Disciplinary Core Idea, and the focus Crosscutting Concept (Systems & System Models). While students may not have completely internalized the concept at this point in the module, having students discuss it and make connections to it whenever possible is a good way to reinforce the idea.

Teacher Tip

- ✓ Before the discussion about the human body as a system of interacting systems, you may want to review what a system is with students. Keep the definition simple so as not to add confusion: ex. a system is a thing made of parts that work together.

5. **Modeling the circulatory system:** Have students use their list to add the circulatory system to their models. Support them in particular in creating two different pathways from the heart to the lungs and back and from the heart to the rest of the body and back. Also remind them that some things they wanted to put in their model should go in a few different places (ex. oxygen and carbon dioxide). See the sample model at the end of the activity for ideas to help students.

   If students get stuck trying to draw a realistic model, remind them that their goal is to show how oxygen gets to all the parts of their bodies, not to draw the human body.

   Again, once they are done, have students share their revised models to get feedback, and give them time to make revisions afterwards.

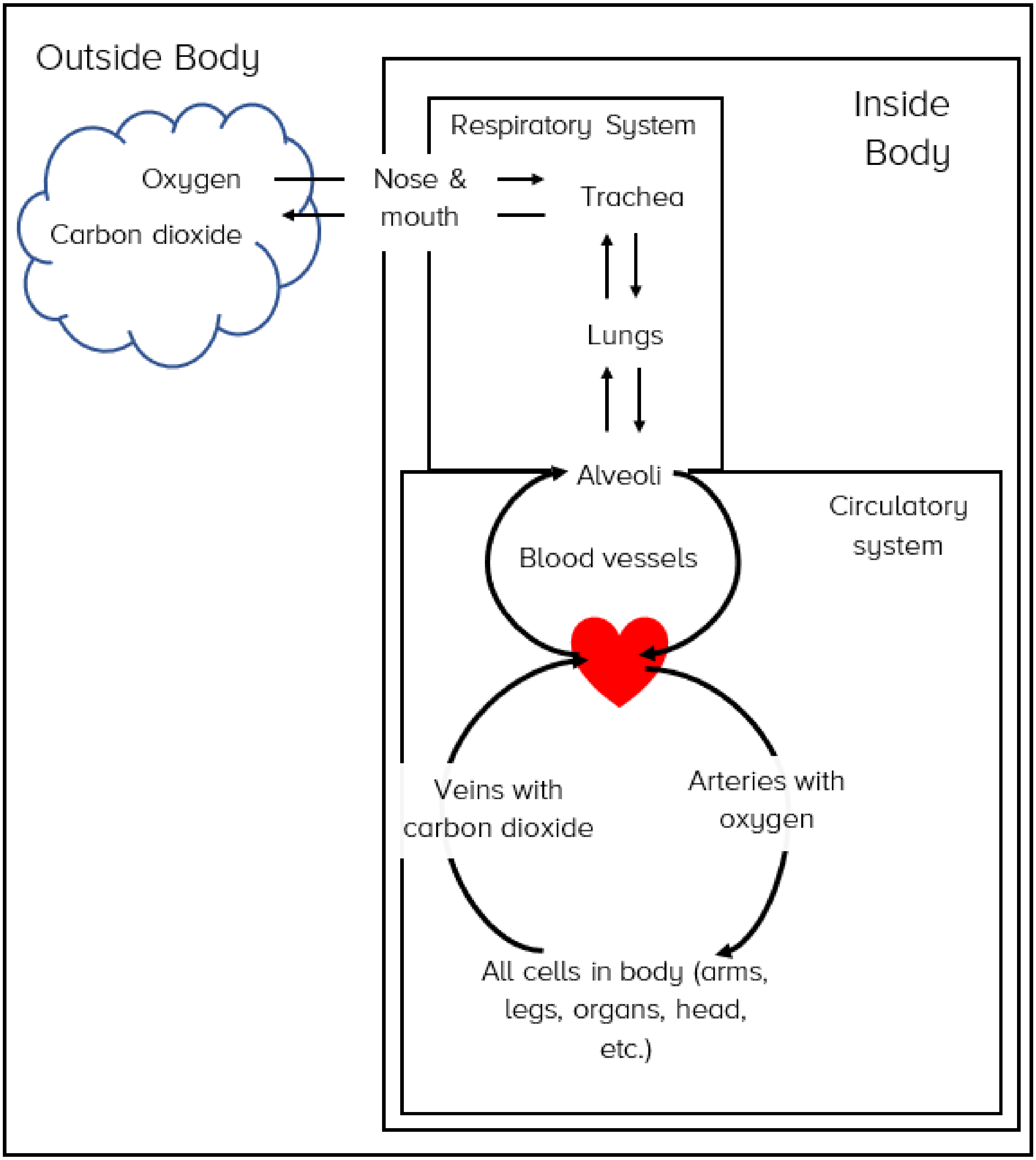
6. **Model discussion.** Lead a discussion with students about how their models show how the human circulatory and respiratory systems are connected. Key points:
   - oxygen gets into our bodies through the respiratory system (nose/mouse, trachea, lungs, alveoli)
   - alveoli allow oxyen to get into our bloodstream.
   - The blood, pumped by the heart, delivers the oxygen to our cells.

   Write the sentence, "The human body is a system of interacting systems" in a place where students can see it such as on the board or a piece of chart paper. Make sure students know what the word "system" means (see sidebar) and what the word "interacting" means, and then have them turn to a partner to decide if they agree or disagree with this statement, and what evidence they have to support their decision. After they have had time to talk, bring the class back together to talk. Students should be able to formulate the idea that the statement is true because the circulatory syste m and the respiratory system interact, and so do lots of other systems in the human body (even if they don't know the names of other systems).

7. **Formative Assessment (Return to the Phenomenon):** Ask students how they can use their models to help understand Tatiana & Calvin's problem. What do you think might be causing Tatiana & Calvin's breathing problem? Why is it worse when they exercise?
    - Possible explanations: Something in the air is keeping them from getting enough oxygen to their bodies through her lungs, something is wrong with their lungs/respiratory system.
    - It is less important at this point that students have "correct" answers than that they are using their models to help make logical hypotheses.

TEACHER NOTES

Sample Respiratory-Circulatory System Model



Activity 5 (Explore): Seeing Ozone's Effects on Living Things

Activity summary: In this activity, students examine ozone damage to leaves as a way to understand what happens to human lungs from exposure to ozone.

Standards Connection
DCI: LS 2.A: Interdependent Relationships in Ecosystems
SEP: Constructing Explanations
CCC: Cause & Effect

Warmup: We know that Tatiana and Calvin have trouble breathing sometimes. It is worse when they exercise, and it's also worse when they're outside a lot. Why do you think this is?

- Guide student discussion around the idea that environmental factors (like pollen, dust, air pollution, etc.) can affect our respiratory system.

1. **Frame the activity:** Tell students that when scientists identify an "effect" like an asthma attack, they are often curious about what is causing it. Remind students about Activity 1 when they discussed what might be causing Tatiana and Calvin's asthma attacks, and what might be causing asthma rates to be higher in some places. If they think that something in the air is causing it to be harder for Tatiana and Calvin to breathe, then they need to learn more about how things in the air affect living things. They can't cut open Tatiana's lungs, so instead they're going to look at plants to see how gases in the air affect them. Hand out the Leaf Investigation Lab sheets to students.

2. **Introduce ozone-damaged leaves**: Show students what ozone-damaged plant leaves look like. You can do this by taking them outside, bringing leaves inside, or showing them pictures like this tulip poplar leaf:

   Have students make observations of what they see and write them on the observation (right) side of their sheets.

Source: Michał Długosz, Wikimedia Commons

3. **Ozone damage discussion:** Ask students if they think the leaves are heathy. Why or why not? (you may want to show them healthy leaves for comparison). Ask students if they think the spots are a cause of something or an effect (they should say effect). Have them write "effect" on their papers next to where it says "observations." Then ask them what

ACTIVITY DETAILS

Time: 45-60 minutes

Objectives
- ✓ Students will understand that gases in the air (ozone in particular) can damage the delicate parts of living things

Materials
- ✓ Ozone damaged-leaves (pictures or actual leaves)
- ✓ Microscopes (optional)
- ✓ Leaf underside wet mount slides (optional)
- ✓ Projector & speakers

Handouts
- ✓ Leaf investigation lab sheet

Teacher Tip
- ✓ If you plan to use microscope slides o leaf undersides, make sure to prep the slides in advance and check to make sure you can see the stomata. Use this video on how to prep the slides: https://www.youtube.com/watch?v=5uv4lIWDECs

TEACHER NOTES

Teacher Tip

- ✓ Learn how to identify ozone-damaged leaves here: http://www.sicktree.com/pubs/ozone/r8-pr25/ozoneh2.htm#:~:text=Normally%2C%20the%20ozone%2Dinjured%20leaf,also%20drop%20their%20leaves%20early.

Teacher Tip

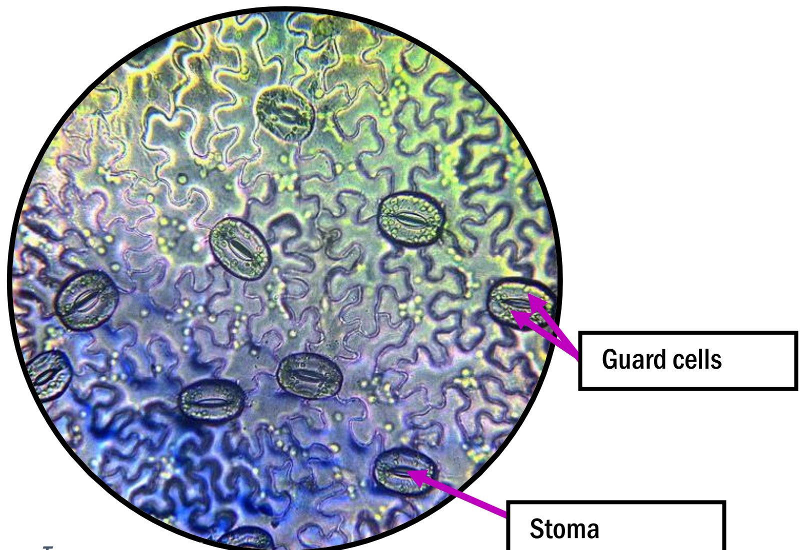
- ✓ This part of the activity is another good place to reinforce students' understanding of cells, and where they fit into the hierarchy of cells-tissues-organs-organ systems. You can also make a connection to red blood cells, which students learned about in Activity 3.

Teacher Tip

- ✓ Don't get bogged down in teaching students about stomata. The goal here is to help them understand that ozone can damage the inside of living things

they think might be causing this effect. Have them write the potential causes on the "cause" side of their sheets. These don't need to be correct (they should be hypotheses such as acid rain, insects, diseases, etc.). Ask students if they think gases in the air can cause damage like this.

4. **Take a closer look:** Tell students that you are going to look more closely at the cells on the underside of the leaves. If microscopes are available, have students look at peelings from under the leaves. If not, show them photographs of the undersides of the leaves through a microscope like the one shown on the next page.



Source: Tyanna Wikimedia Commons

Have students write their observations in the space on their lab sheets. Make sure students see and describe the stomata (little "mouths" on the leaf undersides).

5. **Stomata discussion:** Ask students a variety of questions to help them build understanding of stomata. Students may want to take notes on their lab sheets. Possible questions & answers:
   - What do stomata look like? (they look like lips, little mouths, donuts, etc.) *NOTE: the stomata are the pores (the holes) in the middle. The "guard cells" are the sides.*
   - What structure is a stoma made of? (it is a hole with two curved cells on the sides).
   - What do you think the function of a stoma and guard cells is? (to let things in and out of the leaves, and to keep things from getting in or out when they close)
   - What do you think can get in and out of the *undersides* of leaves? (gases like oxygen, carbon dioxide)
   - What gas do plants need to grow? (Carbon dioxide)

6. **Return to cause & effect:** Go back to students' original hypotheses about what might be causing the damage to these leaves. See if they have a better sense of what the correct cause is and why other causes are unlikely (ex. insect damage looks like little bites taken out of leaves). After discussion, tell students that damage like this is caused by something getting *inside* the leaves. In this case the leaves have ozone damage. Ask if any students have heard of ozone before.

7. **Ozone and plants reading:** Have students read the paragraph about ozone on their handout and answer the questions below the text. Answers:
    - Ozone is a gas
    - Ozone near the surface is harmful to living things
    - Ozone high up in the atmosphere is good for living things
    - Ozone prevents plant leaves from performing photosynthesis well

8. **Ozone gardens (optional):** Show students the video *Plants & Ozone Pollution* (link: https://youtu.be/77cCc16dTVo) starting at :52.

9. **Connecting the dots: Trees, lungs, and ozone damage.** Show students the picture below and ask them what they see. They will likely say this is a tree, but it's actually an upside-down casting of human lungs.

Source: Centre for Research Collections University of Edinburgh
Wikimedia Commons

Take a moment to point out to students where the trachea, bronchi, and alveoli are in the casting. Ask them where in the picture oxygen goes from the lungs to the circulatory system (at the very tips of the bronchioles, where the alveoli are). Then have them

TEACHER NOTES

Multimedia

✓ In the fluorescence photograph found here, the plant leaves on the right were grown with elevated ozone levels, and the leaves on the right were grown under normal conditions: https://earthobservatory.nasa.gov/ContentFeature/OzoneWeBreathe/Images/fluorescence.jpg

Read more about the research here: https://earthobservatory.nasa.gov/features/OzoneWeBreathe/ozone_we_breathe3.php

Clarification

✓ There are many similarities and differences between plant leaves and human lungs, especially the fact that they are where the organism has maximum surface area for gas exchange. Use the analogy to foster student understanding, but don't push it too far because it will get unnecessarily complex and may lead to student misconceptions.

TEACHER NOTES

Extension

- ✓ If time permits, have students make a Venn diagram showing how trees and human lungs are alike and different in terms of how they take in and release gases they need to survive.

Differentiation

- ✓ Discuss the formative assessment question before having students write out their answers.

think about a tree. Where does the carbon dioxide and the oxygen come in and out of trees? It is in the leaves, which are at the very tips of tree branches. Ask students when it comes to breathing, how are human lungs like trees? Focus the discussion to reach key points:

- Both trees and human lungs take in and releases gases they need to survive.
- Both trees and human lungs transfer gases at the tips of long "branches".

Next, ask students how human lungs are different from trees when it comes to breathing. Focus the discussion to reach these key points:

- Trees take in and release gases directly from their leaves. Humans need to breathe the gases into their lungs first from outside their bodies.
- Humans have alveoli where the gases are transferred in and out. Trees have stomata where gases are transferred in and out.

Finally, remind students where the ozone damage is in trees. Then have them consider where ozone damage might be in a human. Give them time to discuss with a partner before moving to the formative assessment.

10. **Return to the KWL chart:** Have students take out the KWL charts they created in Activity 1 and display the class KWL chart you made. Have students identify anything new they've learned that helps them to understand the phenomenon. For example:
    - Ozone is a gas in the atmosphere
    - Ozone can damage delicate parts of living things like the insides of plant leaves

11. **Formative Assessment:** Have students write a hypothesis based on what we learned today about why they think Tatiana and Calvin have a hard time breathing when they go outside. Their hypothesis should include something about how gases (like ozone) can affect the insides of living things. Key points:
    - Tatiana and Calvin may have irritated or damaged lungs because of ozone. Ozone is a gas that is a kind of air pollution. Ozone can get into living things and damage them. If it got into Tatiana and Calvin's lungs, it may be hurting them.

STUDENT HANDOUT

Name ____________________

Leaf Investigation Lab

Cause	Observations
what do you think caused the leaf to look like that?	what does the leaf look like?

Observations of leaf undersides through a microscope. What do you see?

Ozone & Living Things

Ozone is a gas made of oxygen that is found in Earth's atmosphere. When it is formed high in the atmosphere, ozone is helpful for living things because it can block harmful radiation from the sun. However, when ozone is formed close to Earth's surface, it can damage the delicate parts of living things. This kind of ozone is formed from air pollution that comes from cars, trucks, and power plants. Ozone enters trees and other plants through their stomata and can damage the leaves so that they cannot perform photosynthesis well. Ozone can also be harmful to humans if they breathe it in, especially if the person who breathes it already has problems with their respiratory system.

1. What is ozone? ____________________
2. What kind of ozone is harmful to living things? ____________________
3. What kind of ozone is helpful to living things? ____________________
4. What effect does ozone have on the inside of plant leaves?

____

____

Summary

Write a hypothesis based on what we learned today about why Tatiana and Calvin have a hard time breathing when they go outside. Your hypothesis should include what you know about ozone and how it can affect the insides of living things.

____

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Activity 6 (Explain): Air Pollution & Humans

Activity summary: Students use the Lung Attack simulation to deepen their understanding of how air pollution affects human lungs. Then they use this information to add to/revise their models of the circulatory and respiratory systems.

Standards Connection

DCI: LS 1.A: Structure & Function
SEP: Developing & Using Models
CCC: Systems & System Models; Cause & Effect

Warmup: What were Tatiana and Calvin's symptoms that we talked about at the beginning of this investigation?

- Use this as an opportunity to remind students of the phenomenon they are investigating so they can connect it to the simulation they are doing in this activity.

1. **Frame the activity:** During our last activity, we saw how ozone can harm plants. At the end of the last activity, we came up with some hypotheses about how ozone could be affecting Tatiana and Calvin. Today we're going to look more carefully at how ozone and other pollutants affect human lungs to see if it supports our hypotheses.

- **Lung Attack Part 2 (ozone & particulate matter):** Have students take out their KWL charts from Activity 1 (if they need more space they can use another chart). Either using students computers, or together as a class, have students continue the Lung Attack simulation: http://web1.pima.gov/deq/lungattack/lungplay.htm) with Ozone, PM10, and PM2.5. As they work through the simulation, have them add new details from what they learn to their KWL chart. Key takeaways:
    - Ozone attacks the cells in your bronchi
    - Ozone can trigger asthma attacks
    - Big particulate matter (PM10) is dirt, dust, mold, spores, pollen, etc.
    - PM 10 can block airways and make you cough
    - Small particulate matter (PM2.5) is made of heavy metals and other toxins
    - PM 2.5 can make you cough or make it hard to breathe. They can also cause cancer.

ACTIVITY DETAILS

Time: 30-45 minutes

Objectives

- ✓ Students will deepen their understanding of how air pollution affects human lungs
- ✓ Students will determine how air pollution (ozone and particulate matter) fit into their models of the circulatory/respiratory systems

Materials

- ✓ Student computers
- ✓ Computer & projector

Handouts

- ✓ Models (from Activity 4)
- ✓ KWL chart (from Activity 1)
- ✓ Asthma Attacks: Cause & Effect

Teacher Tip

- ✓ This module focuses on ozone as a cause of asthma attacks, but particulate matter (PM) is mentioned here because it is another pollutant that can have similar effects. PM is addressed much more

TEACHER NOTES

Modifications

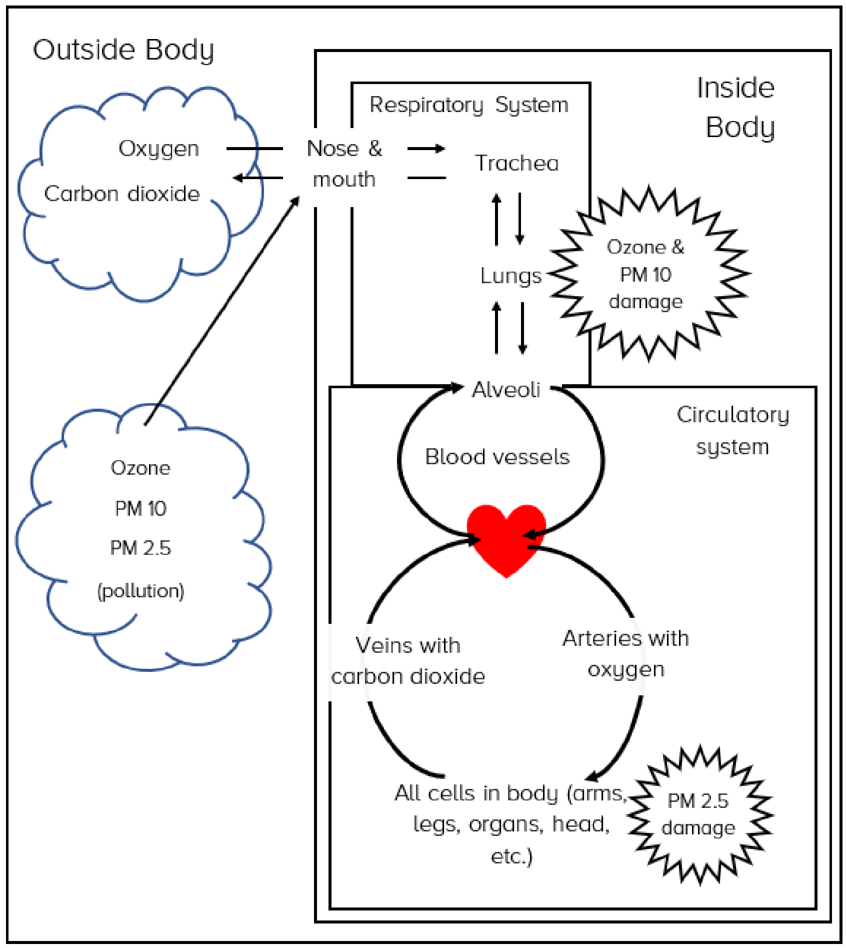
- ✓ Provide students with slips of paper with the new parts to add to their model (as in Activity 4)
- ✓ If students don't have their models from Activity 4, have some generic models that they can start from for this Activity

Differentiation

- ✓ Create a list of questions for students to answer while doing the Lung Attack simulation

After students have finished, you may want to have students share what they learned and add it to the class KWL chart. This is also a good time to clarify misconceptions and make sure all students understand the key takeaways.

- **Modeling air pollution and humans.** Have students take out their models of how the lungs and respiratory system work. Have them add ozone, PM10, and PM2.5 to their models. Their revised models might look something like this:



- **Return to the original phenomenon.** Remind students that they are acting as medical professionals for this investigation, and it is time to make their final diagnosis and explanation for Tatiana and Calvin. Have students take out their original Patient Record Sheets from Activity 1, the KWL charts they have been filling out, and their CER from Activity 2. Have students think about what might be causing Tatiana and Calvin's asthma attacks based on all the evidence they have so far, including the sources of respiratory problems that they have learned about in this module. In groups, have them develop a list of follow up questions that they want to ask Tatiana and Calvin to help with their diagnosis. See potential questions below.

  Have students ask their questions, and either answer them yourself, or have your original student actors answer. Key questions & answers:
  - Q: Is the air near you polluted? A: They don't really know the answer to this, but they do live near a busy road that has lots of trucks.
  - Q: Is there a lot of dust in the air near where you live? A: Yes
  - Q: Do you go outside a lot? A: Yes, they love to play outside
  - Q: Is it harder to breathe when there is traffic? A: Yes

- **Formative assessment:** Once students have asked enough questions to get to the heart of the phenomenon, pass out the Asthma Attacks: Cause & Effect sheet and have them write a complete "cause" to the "effect" of Tatiana &/or Calvin's symptoms, including why it is hard for them to exercise. Their explanation must address what is causing the asthma attacks and what that cause does to their bodies. Students should be encouraged to use their notes to answer the prompts.
  - Sample explanation (part 1): Tatiana and Calvin have asthma. Air pollution from the busy road near where they live causes them to have asthma attacks. The air pollution (ozone & PM) irritates their lungs (respiratory system) which makes it hard for them to breathe.
  - Sample explanation (part 2): Tatiana and Calvin have difficulty exercising because people need oxygen to operate. We get oxygen into our bodies through our respiratory systems, and to our cells through our circulatory systems. Since Tatiana and Calvin have problems with their respiratory systems, they have a hard time getting enough oxygen to their bodies, which makes it hard to exercise.

Name____

Modification

- ✓ Before having students come up with their set of questions to ask Tatiana and Calvin, have them summarize their learning in their small groups using their KWL charts.

Clarification

- ✓ There are many different things that can cause an asthma attack including acid reflux, respiratory infections, stress, and even dry air. In this module, the focus is on air pollution – specifically ozone and particulate matter– as a cause. Make sure students realize that not all asthma attacks are caused by air pollution.

Asthma Attacks: Cause & Effect

Based on the evidence you have gathered, write an explanation for what is causing Tatiana and Calvin to have asthma attacks. Your answer should identify what you think is causing the attacks and what specific parts and systems of their bodies are affected by the cause.

Tatiana and Calvin both have difficulty exercising. Explain how asthma might could make it hard for them to run or do other exercises for a long time. Your answer should identify what body systems are involved in supplying your body with the things it needs to operate.

Activity 7 (Elaborate): Asthma & the AQI

Activity summary: In this activity, students learn how the EPA summarizes air quality using the Air Quality Index (AQI) and what behaviors are recommended when air quality is bad. They also learn what an asthma inhaler does (optional).

ACTIVITY DETAILS

Time: 45-60 minutes

Objectives

- ✓ Students will learn how to determine if air quality on a given day is good or bad
- ✓ Students will learn about how asthma inhalers help people to breathe (optional) and how to help someone who is having an asthma attack

Materials

- ✓ Student smartphones (if permitted)
- ✓ Computer & projector
- ✓ Student computers (optional)
- ✓ Markers/colored pencils (optional)

Handouts

- ✓ Understanding the AQI

Standards Connection

DCI: LS 2.A: Interdependent Relationships in Ecosystems

Warmup: What do you think you can do to protect your respiratory system from pollution?

- Stay inside if the pollution is bad, play in places that have less pollution

1. **Frame the activity:** Now that we know Tatiana and Calvin have trouble breathing because of asthma and air pollution, what recommendations can we make to them? As medical professionals, we need to find ways to help them stay safe and let them stay active.

2. **Looking up the Air Quality Index (AQI).** Show students the Clean Air Partners website for current and forecasted AQI (either on the projector, or their own computers): https://www.cleanairpartners.net/current-and-forecasted-air-quality

   Click on current to show the current air quality. Ask students what they can tell from the website about the current air quality where they live. The information should be very easy for students to find and understand.

3. **Looking up the AQI forecast.** Click on "forecasts" and ask students what they can tell from the website about the forecast for the air quality for the next two days.
   - Air quality is likely to be good (green) unless it is ozone season (late spring to early fall) or there are local events that cause PM2.5 to be high. AQI in the United States rarely gets into the red zone, although localized air quality can be bad, especially due to particular events.

TEACHER NOTES

Modifications

- ✓ Instead of having student group create fictional scenes, have them create short presentations about their AQI level. They can then give each other feedback on their presentations using a peer feedback rubric like this one: https://www.teacherspayteachers.com/Product/Presentation-Partner-Peer-Review-Rubric-4409187

Teacher Tip

- ✓ Be sure to follow your school's technology policy with regard to student devices, and remind students to talk to their parents about installing any software on their phones. This is also a good way for students to teach their parents how to monitor air quality.

Differentiation

- ✓ Create student scenes in advance, and have groups add details before presenting OR have all students read the scenes individually and decide what the AQI level is.

4. **Understanding the AQI scale.** Give students the "Understanding the AQI" handout and project it. If the student copies are in black & white, they can color in the AQI levels (optional). Note that the color names are written on the chart. Tell students that the United States Environmental Protection Agency (EPA) uses the AQI scale to let people know how safe the air is to breathe. Briefly review with students what the colors mean, and what steps should be taken for each color level.

5. **Stay safe scenarios.** Divide the class into 5 groups and tell students that they are going to be creating and presenting short scenes (30-60 seconds) showing what people should do to be safe when the AQI is at different levels. Each group will present their scene, and the class will have to guess what the AQI level is for the scene. You may want to provide an example of a scene (ex. holding soccer practice indoors if AQI is orange).

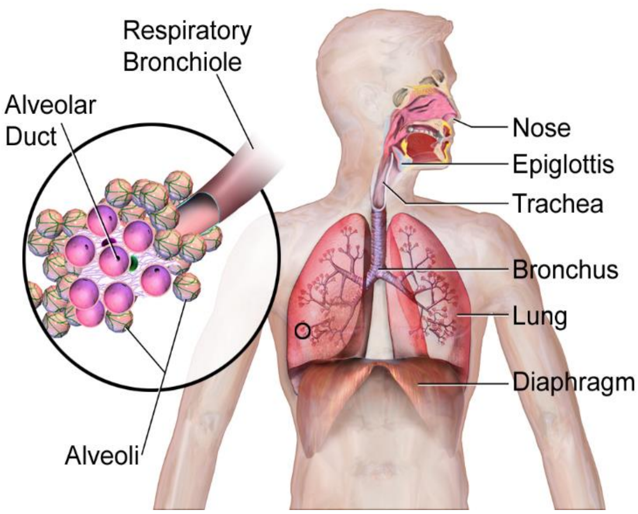
   In secret, assign each group one of the AQI levels. Circulate around the class to help students brainstorm their scenes. Once each group has a scene, and they have had a chance to practice, give each group time to present their scene, and have the other students use their AQI charts to try to guess what the AQI level is in the scene.

6. **Finding the AQI.** Share other ways that students can look up the AQI, for example using apps on their phones such as Clean Air Partners Air Quality app, and the Air Visual app. If students are allowed to use their smartphones at school, show them how they can add these apps to their phones.

7. **Understanding asthma inhalers (optional).** Show students a picture of an inhaler like the one below (or an actual inhaler if you have one), and ask them if they know what it is (at least one student will likely recognize it).

Ask students if they know what the inhaler is for. They will likely respond that it helps you to breathe. Tell students that sometimes air pollution can cause people to have asthma attacks even if they follow the AQI guidelines.

Tell students that inhalers are a way to quickly deliver medicine into your lungs. The medicine in most inhalers is called a "bronchodilator". Take a moment to break down this word for students by using the picture of the lungs from earlier in the unit so they can see where the bronchi and bronchioles are. Also explain to them what the word "dilate" means (expand) and ask them if they've ever had their eyes dilated at the eye doctor. See if they can figure out what a bronchodilator does (it opens up the air passages in your lungs).



Source: https://upload.wikimedia.org/wikipedia/commons/e/e7/Respiratory_System_%28Illustration%29.png

Tell students that the best possible thing they can do for someone who is having an asthma attack is to get their inhaler. They can also help by having the person sit upright and talk to them calmly. If they are having severe trouble breathing, call 911.

8. **Formative assessment:** Tell students to imagine that the EPA is predicting that tomorrow will be an orange AQI day. Have them make a list of 3 recommendations for Tatiana and Calvin to make sure they are safe from air pollution.
   - Possible responses: play a board game indoors instead of playing outside, taking their asthma inhaler to school, carpooling to school instead of walking, play basketball in the school gym instead of outside, etc.

TEACHER NOTES

Follow up to phenomenon video

- ✓ If you showed students the video "Between Life and Breath" for the phenomenon, the end of this activity is a good time to show it again with the ending. If you haven't used the video before you can also show it now to give students an idea of how to reach to a person having an asthma attack and the importance of having an inhaler nearby. The video can be found at: https://www.youtube.com/watch?v=OCosTBwG4Pg

Next steps

- ✓ This is the last activity in the module before the final assessment. You may want to have students review their KWL charts and add any details, or review their models before the end of module assessment.

UNDERSTANDING THE AQI*

Air Quality Action Guide

AQI Value	Level of Health Concern	Colors	Action Steps to Protect Your Health and Our Environment
0 – 50	Good	Green	Enjoy outdoor activities.
51 – 100	Moderate	Yellow	Air quality may pose a moderate risk, especially for those who are unusually sensitive to air pollution.
101 – 150	Unhealthy for Sensitive Groups	Orange	Children and active adults, people with respiratory disease, such as asthma and emphysema, and heart ailments should limit prolonged outdoor physical activity.
151 – 200	Unhealthy	Red	Sensitive groups in particular should avoid outdoor physical activities. Everyone else, especially children, should limit prolonged outdoor exertion.
201 – 300	Very Unhealthy	Purple	Everyone is strongly urged to follow all of the action steps listed previously AND avoid outdoor physical activities.

*Air Quality Index

Activity 8 (Evaluate): Modeling Air Pollution & Human Health

Activity summary: For this final activity, students demonstrate what they have learned in the module about air pollution and human health by completing an assessment.

Standards Connection

DCI: LS 1.A: Structure & Function
DCI: LS 2.A: Interdependent Relationships in Ecosystems
SEP: Developing & Using Models; Constructing Explanations
CCC: Systems & System Models; Cause & Effect

Warmup: Choose a warmup based upon something from this module you want to review with students before the assessment.

1. **Frame the activity:** During this investigation, you have acted as medical professionals to diagnose your patients – Tatiana and Calvin – and get to the root cause of their problem. You have figured out what is causing their asthma to give them problems, and you have learned how the respiratory and circulatory systems work together to provide your body with oxygen. Today you are going to share what you've learned to show what you know.

2. **Summative assessment.** Provide the assessment to students and support as necessary.

3. **Grading & feedback.** Use the scoring guide provided to grade the assessment and provide feedback to students.

ACTIVITY DETAILS

Time: 30 minutes

Objectives

- ✓ Students will demonstrate what they have learned in the module about modeling the respiratory and circulatory systems, and the effect of air pollution on humans.

Handouts

- ✓ Our Lungs, Our Air, Our Health assessment

Differentiation

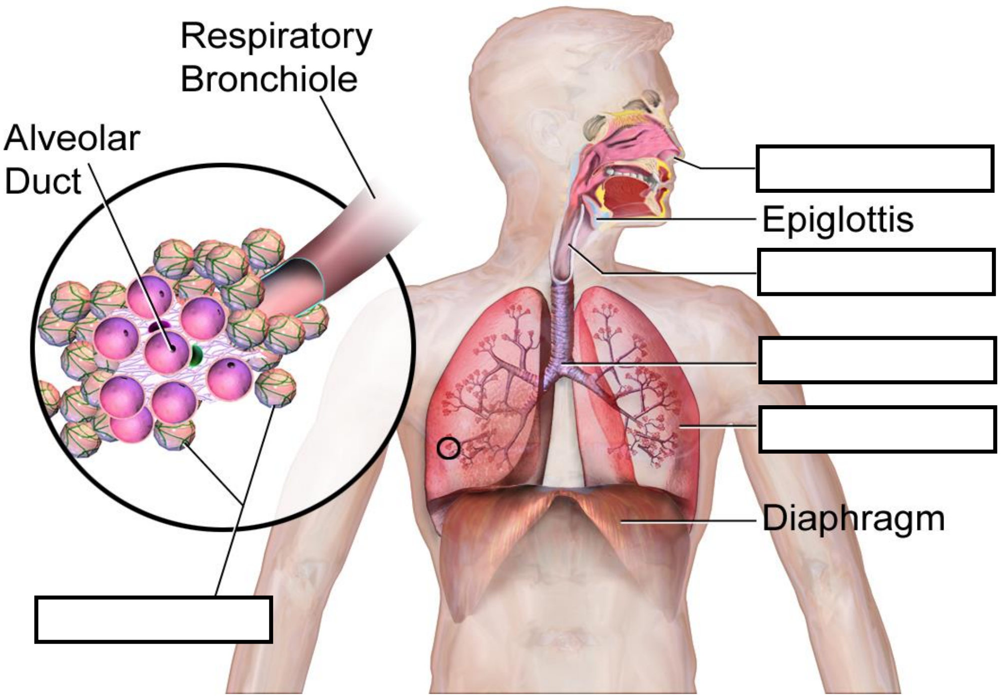
- ✓ Instead of having students write the constructed response answers completely, provide sentence starters or make the responses fill-in-the-blank with key concepts left blank for students to fill in.
- ✓ For an added challenge, remove some of the parts of the model and have students add them in as part of the assessment.

Name____

Our Lungs, Our Air, Our Health Module Assessment

Part 1: Organs of the Respiratory System

Directions: Use the word bank on the right to label the missing parts of the respiratory system in the diagram:



Word Bank

Lung

Trachea

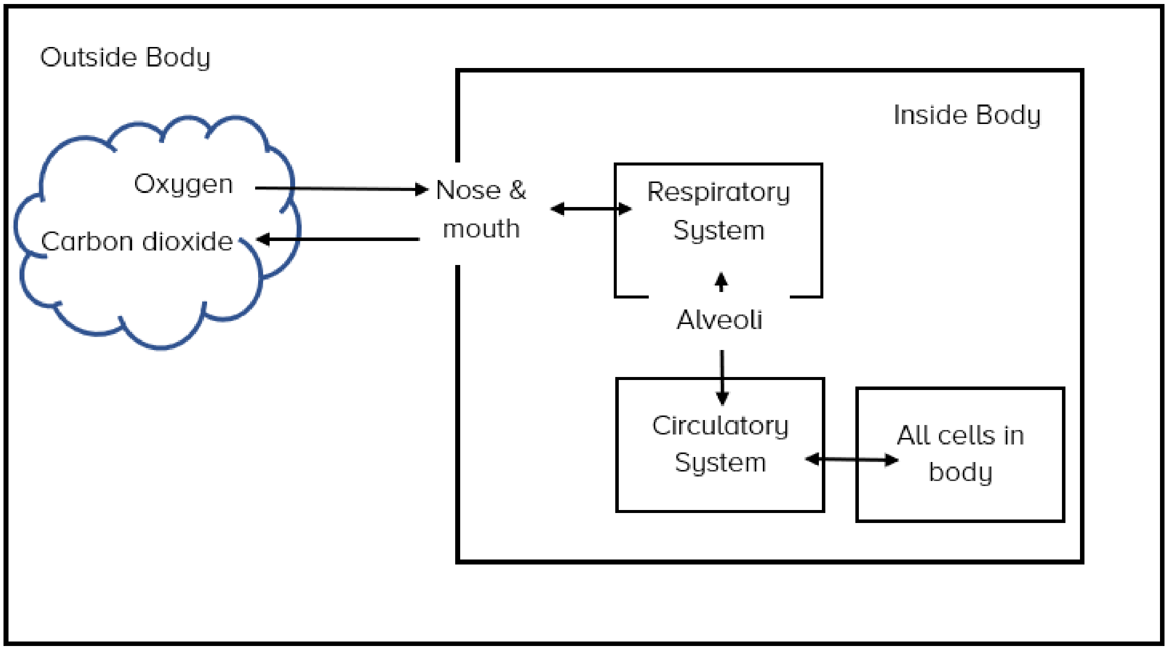
Alveoli

Nose

Bronchi

Part 2: The respiratory and circulatory systems

Directions: The simplified model below shows the human respiratory and circulatory systems. Use the model to answer the questions below.



Use the model to explain the path of oxygen from the environment outside the body to the cells in your body. Make sure to include parts of the circulatory and respiratory systems in your answer.

Explain why the arrows in the model go in two directions inside the body.

Part 3: The Human Body: A System of Systems

The human body is called a system of interacting systems. Explain what this means in your own words. In your answer…

- Briefly explain what a system is
- Use at least one example from what you have done or learned in this unit to support your answer.

SCORING GUIDE

Part 4: Air pollution

Add ozone to the model showing how it gets into the human body and what parts of humans it affects.

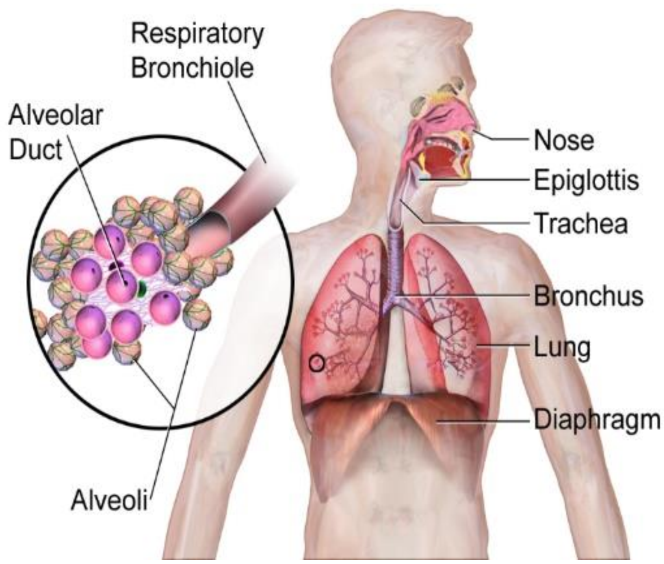
Add particulate matter 2.5 (PM 2.5) to the model showing how it gets into the human body and what parts of humans it affects.

Air pollution can make asthma worse when humans breathe it in. Air pollution is a cause, and an asthma attack is the effect. Explain how air pollution can cause an asthma attack. You can use the diagram on the first page and the model on the second page to help with your answer.

Our Lungs, Our Air, Our Health Module Assessment
Teacher Scoring Guide

		Points possible
Part 1	**Organs of the Respiratory System**	**5**
Part 2	**Modeling the Respiratory & Circulatory Systems**	**15**
Part 3	**The Human Body: A System of Systems**	**5**
Part 3	**Air pollution**	**10**
	Total Points	**30**

Part 1: Parts of the Respiratory System (5 points): One point for each correct answer



Source: https://upload.wikimedia.org/wikipedia/commons/e/e7/Respiratory_System_%28Illustration%29.png

Part 2: The Respiratory & Circulatory Systems (10 points)

Sample response:

- Oxygen enters the body through your nose and mouth when you breathe in. It travels down your trachea and into your lungs. When it reaches your alveoli, it goes out of the alveoli into your blood vessels. The heart pumps blood around the circulatory system. This caries the oxygen to all the cells of your body.
- The arrows go in two directions inside the body because oxygen is going to your cells from outside your body, and carbon dioxide is going from your cells to the environment in the opposite direction.

Points	Description
10	Student thoroughly and accurately describes the path of oxygen from the environment to parts of the body, including accurate scientific terminology for parts of the respiratory and circulatory systems. Student accurately explain why the arrows in the body go in two directions in the model.
8	Student describes the path of oxygen from the environment to parts of the body, but does not use accurate scientific terminology or includes a minor error in the pathway **OR** Student does not accurately explain why the arrows in the body go in two directions in the model
6	Student's description of the path of oxygen to parts of the body is partially correct but includes significant errors. Student does not accurately explain why the arrows in the body go in two directions in the model.
3	Student's description of the path of oxygen is incorrect and their answer does not explain why the arrows in the body go in two directions in the model.

Part 3: The Human Body: A System of Systems

- Sample response: The human body is called a system of interacting systems because a person is a system: it has a bunch of parts that work together, and those things have a bunch of parts that work together. For example, we have a circulatory system and a respiratory system that work together. They also have parts that work together. They are interacting because they depend on each other. The respiratory system gets oxygen from the air and gives it to the circulatory system to deliver. When we did our experiment with breathing and heart rate, when my partner exercised, his heart rate and his breathing both went up because the systems are connected.

Points	Description
5	Student's explanation is accurate and provides a meaningful example from the module to support it. They either explicitly or through their explanation, define what a system is.
4	Student's explanation is mostly accurate and provides an example from the module to support it. They may or may not define what a system is.
3	Student's explanation is on topic, but does not make it clear how the human body is system of systems. The example from the module is connected to systems but does not show how the body is a system of systems. They may or may not define what a system is.
3	Student's explanation is incorrect and shows significant misunderstanding of the concept. They may or may not have an example from the module and may or may not define what a system is.

Part 3: Air Pollution

Sample response:

- Model shows ozone entering the body through the nose and mouth, and affecting the lungs.
- Model shows PM 25. Entering the body through the nose and mouth, and affecting the lungs and "all cells of the body".
- Air pollution can cause an asthma attack because when ozone gets into your lungs, it irritates your bronchi and bronchioles in your lungs. When this happens, your lungs make mucus to stop the irritation. The mucus can make it hard for you to breathe. It also makes you cough. These can cause an asthma attack to happen.

Points	Description
10	Student accurately shows how pollution gets into the body and what parts of the body are affected by ozone and PM 2.5. Student thoroughly and accurately describes how air pollution can cause an asthma attack using appropriate scientific terminology.
8	Student has minor errors in either in the parts of the body that are affected by ozone and PM 2.5 OR in how air pollution can cause an asthma attack.
6	Student's response shows some understanding of how air pollution affects the body, but the response has significant errors in the parts of the body that are affected by ozone and PM 2.5 and in how air pollution can cause an asthma attack.
3	Student's response about how air pollution affects the body is mostly incorrect but shows some understanding.

Doing Our Part

- Plant an ozone garden at your school to identify whether ozone reaches harmful levels in your community. Specific species of plants are particularly sensitive to ozone and can indicate whether your community has an ozone problem. Learn more here: https://www.earthsciweek.org/classroom-activities/plant-ozone-monitoring-garden

- Look up the AQI using a computer or install an air quality app on your phone or your parents' phone. Use the AQI so you know when and how to avoid air pollution, especially on bad days.

- Be prepared for bad air quality situations, especially if you have asthma. For example, take your inhaler with you when the AQI is bad, and think about how you can get home from school if the air quality is bad. If you know someone with asthma, remember what you can do if they have an asthma attack and need your help.

- Avoid places where you know the air quality is likely to be bad, such as near roadways with lots of traffic (especially big trucks) or near power, cement, and chemical plants that are in your neighborhood. When walking to school, choose a route that stays away from busy streets.

- If you sometimes have difficulty breathing, talk to your parent(s) or doctor so they can make sure you get the help you need.

About this section

This section in included in every module either as a list or as part of an activity. It describes actions students can take to mitigate the effects of air pollution in their lives, and to help prevent air pollution from getting into the atmosphere. Many of these suggestions are the same from module to module, but there are variations depending on the focus of the module.

While the actions from this section are not explicitly built into the curriculum, they can be used in various ways to motivate students and provide them opportunities to take action to make a difference in their community.

Air Quality Champion in our Community

Name: Dr. Janet Phoenix
Title: Assistant Research Professor
Organization: George Washington University

How does your work relate to air quality?
I manage an asthma home visiting program. We provide education and tools for families to use to improve the health of their children with asthma. We provide vacuum cleaners to reduce allergic dust particles in the home, pest management for roaches and mice and dust mite covers for the bed. Many of the families we serve live in areas of the city where air quality is poor, because of close proximity to roadways. I also teach graduate students at George Washington University about how poverty and poor environmental conditions can contribute to poor health outcomes.

What motivates you to come to work every day?
It motivates me to know that the work we do helps families keep their children healthy. I also like training the future health care workforce.

How did your education lead you to the position that you have today?
I majored in Anthropology in college, and I studied how culture, beliefs and health intersect. That was a great foundation for medical school at Howard University. After medical school I studied at the Bloomberg School of Public Health at Johns Hopkins University.

What is your workspace like?
My office at George Washington University is in the middle of a densely populated urban center: Washington, D.C. When I am not conducting research, I am out in the city working with families of children with asthma. I also collaborate with organizations and agencies in the city that deal with asthma. Some of these agencies are responsible for improving housing conditions that make asthma worse like leaks and mold. I also work with agencies to write laws and enforce environmental regulations in order to keep people safer.

What accomplishment are you most proud of?
I am proud of forming a coalition called the Healthy Housing Collaborative. This group is working to improve housing conditions related to health for DC residents.

Is there something important that you want to share that we haven't asked?
I underestimated the role of good public policy (laws and regulations) when I began my career. Without these laws and regulations, it is difficult to keep communities safe from pollution sources that make the air hazardous to breathe. Elected officials don't always know how to keep the air clean. They depend upon citizens and experts to help them write and support environmental laws. It is important for you to understand the laws in your community, so you can make improvements and create new laws that are needed.

Glossary

AQI (Air Quality Index) – a scale for reporting daily air quality. The AQI tells you how clean or polluted the air is in a given location, and what the associated health risks are. The AQI focuses on health effects you may experience within a few hours or days after breathing polluted air.

artery – a muscular tube that is a part of the circulatory system, which carries blood (mainly oxygen-rich) from the heart to all parts of the body.

alveoli (singular alveolus) - tiny sacs in the lungs of mammals (including humans) that allow gases to transfer between the lungs and capillaries. This allows gases to enter and leave the bloodstream.

bronchi (singular bronchus) - passages or airways in the respiratory system that conduct air into the lungs

bronchodilator - a medication that relaxes and opens the airways, or bronchi, in the lungs.

capillary – a fine, branching blood vessel that connects the arteries to the veins in the circulatory system

cardiovascular system – another name for the circulatory system which references the heart (cardio-) and blood vessels (-vascular)

hemoglobin - a protein in human red blood cells that carries oxygen to the body's organs and tissues and transports carbon dioxide from organs and tissues back to the lungs.

ozone (O_3) - a natural and a man-made gas made of three oxygen atoms that occurs in the Earth's upper atmosphere (the stratosphere) and lower atmosphere (the troposphere). Depending on where it is in the atmosphere, ozone affects life on Earth in either good or bad ways.

particulate matter (abbreviation: PM) **-** a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Larger particles are called PM 10, smaller particles are called PM 2.5, based on their diameter in micrometers.

stomata (singular stoma) – a pore, found in the epidermis of leaves, stems, and other organs, that controls the rate of gas exchange into and out of plants.

trachea - (in human anatomy): a large membranous tube reinforced by rings of cartilage, extending from the larynx to the bronchial tubes and conveying air to and from the lungs. Also known as the windpipe

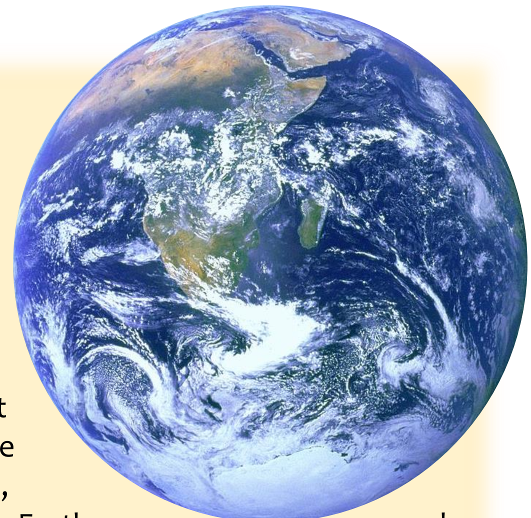
vein – a tube that is part of the circulatory system of the body, which carries blood (mainly oxygen-poor) toward the heart.

MODULE 2

What's the Forecast?

Humans, Weather, and the Story of a Code Red Day

Module Overview



This photograph of Earth, commonly known as "The Blue Marble," was taken by the crew of the Apollo 17 spacecraft. When humans first began taking pictures of Earth from space in the 1960s, air and water pollution had already become huge problems in the United States. Photographs like this one, as well as books like Silent Spring by Rachel Carson, inspired people to take action to save the planet. In 1970 the first Earth Day was held and the Clean Air Act was signed. The modern environmental movement was born. Since then, humans have done a lot to both damage and protect the Earth and its air. In this module, students will investigate a "bad air day" to understand the sources and types of man-made air pollution, focusing on ozone, a common contributor to bad air days in the region. They will also learn about weather, and the complex ways in which weather and air pollution interact. In doing so, they will use the same sophisticated computer models that meteorologists use to predict both the weather and air pollution. Students will also take a historical look at how air quality has changed over time, using both the Air Quality Index (AQI) and EPA data as guides. As a culminating activity, students will use what they have learned to create an air quality report to inform the public about whether their air is safe to breathe.

Anchor phenomenon: A hazy day that occurred in Washington D.C. in July, 2018.

Pacing

- 9 activities + summative assessment project
- Approximately 11-13 45-60 minute class periods + assessment project

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When to Teach This Module

Finding the right place within a science scope and sequence to investigate air pollution with students can be tricky. Below you will find some information about the module that can help you decide where this it might fit into your own plans for student leaning:

- **Connection to Weather:** This module includes a significant connection to weather concepts, but it *does not* go into detail about those concepts. As such, the module would be a great addition to a weather module – either during or after – to incorporate human impacts on Earth's atmosphere. Activity 8 is designed to be a refresher on weather topics and vocabulary, so even if students have studied weather in a previous year, they should be able to engage with the topics of this module.

- **Connection to Natural Resource Usage:** Air pollution is very much a story about human population and the consequences of how we use natural resources. While the module itself does not go into detail about kinds of natural resources, it would fit well as a part of a larger investigation of fossil fuels, and how our usage of those fuels affects the environment. The module is a great way to incorporate human impacts on the environment into a unit on these resources.

Standards Overview

Middle School NGSS standards alignment

Performance Expectations

Focus PE:

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). <u>Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change</u>. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]

Background PE:

MS-ESS3-3. Apply scientific principles to design a method for monitoring ~~and minimizing~~ a human impact on the environment.* [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).]

Science & Engineering Practices

Focus SEP: Developing and Using Models

Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

- ~~Develop or~~ **modify a model—based on evidence – to match what happens if a variable or component of a system is changed.**
- **Use** ~~and/or develop~~ **a model of simple systems with uncertain and less predictable factors**.
- ~~Develop and/or~~ **use a model to predict and/or describe phenomena**.

Background SEP: Obtaining, evaluating, and communicating information

Obtaining, evaluating, and communicating information in 6–8 builds on K–5 experiences and progresses to evaluating the merit and validity of ideas and methods.

- Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings.
- Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations.

Disciplinary Core Ideas

Focus DCI: ESS 3.C: Human Impacts on Earth Systems

Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

Background DCI: ESS 2.D: Weather and Climate

Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. ~~These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns~~.

Crosscutting Concepts

Focus CCC: Patterns – Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

- Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems.
- Graphs, charts, and images can be used to identify patterns in data.

Background CCC: Systems and System Models – A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

NGSS 5th Grade Standards alignment

Performance Expectations:

Focus PE:

5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

Science & Engineering Practices

Focus SEP: Developing and Using Models

Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.

- Develop and/or use models to describe and/or predict phenomena.

Background SEP: Obtaining, evaluating, and communicating information

Obtaining, evaluating, and communicating information in 3–5 builds on K–2 experiences and progresses to evaluating the merit and accuracy of ideas and methods.

- Read and comprehend grade-appropriate complex texts and/or other reliable media to summarize and obtain scientific and technical ideas and describe how they are supported by evidence.
- Compare and/or combine across complex texts and/or other reliable media to support the engagement in other scientific and/or engineering practices.
- Combine information in written text with that contained in corresponding tables, diagrams, and/or charts to support the engagement in other scientific and/or engineering practices.
- Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem.
- Communicate scientific and/or technical information orally and/or in written formats, including various forms of media as well as tables, diagrams, and charts

Disciplinary Core Ideas

Focus DCI: ESS3.C: Human Impacts on Earth Systems

Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. (5-ESS3-1)

ESS 2.A: Earth Materials and Systems

Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather.

Focus CCC: Patterns – Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

- Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena and designed products.
- Patterns of change can be used to make predictions.
- Patterns can be used as evidence to support an explanation.

Background CCC: Systems and System Models – A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

- A system can be described in terms of its components and their interactions.

Virginia Standards of Learning (SOLs) alignment

Science & Engineering Practices	
5.1 (e)	Developing and using models. The student will… • develop models using an analogy, example, or abstract representation to describe a scientific principle or design solution • identify limitations of models
6.1 (e)	Developing and using models. The student will… • use, develop, and revise models to predict and explain phenomena • evaluate limitations of models
Content Standards	
6th Grade 6.9(c)	6.9 The student will investigate and understand that humans impact the environment and individuals can influence public policy decisions related to energy and the environment. Key ideas include c) major health and safety issues are associated with air and water quality
6th Grade 6.7	6.7 The student will investigate and understand that air has properties and that Earth's atmosphere has structure and is dynamic. Key ideas include a) air is a mixture of gaseous elements and compounds; b) the atmosphere has physical characteristics; e) atmospheric measures are used to predict weather conditions; and f) weather maps give basic information about fronts, systems, and weather measurements.
Earth Science ES.11	ES.11 The student will investigate and understand that the atmosphere is a complex, dynamic system and is subject to long-and short-term variations. Key ideas include b) biologic and geologic interactions over long and short time spans change the atmospheric composition; c) natural events and human actions may stress atmospheric regulation mechanisms; and d) human actions, including economic and policy decisions, affect the atmosphere.
Earth Science ES.12	ES.12 The student will investigate and understand that Earth's weather and climate are the result of the interaction of the sun's energy with the atmosphere, oceans, and the land. Key ideas include b) weather patterns can be predicted based on changes in current conditions; d) models based on current conditions are used to predict weather phenomena; and

Common Core State Standards alignment

Literacy Standards	
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
RST.6-8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
SL.8.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.
Math Standards	
6.RP.A.1	Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.
7.RP.A.3	Use proportional relationships to solve multistep ratio and percent problems. Examples: simple interest, tax, markups and markdowns, gratuities and commissions, fees, percent increase and decrease, percent error.

5E Module Flow

Activity 1 (Engage): What's That in the Sky?
Timing: 30-45 minutes
Purpose: Introducing the anchor phenomenon
- ✓ Students will make observations and hypotheses, and ask questions to better understand the anchor phenomenon

Activity 2 (Explain): What is Weather?
Timing: 1-2 class periods
Purpose: Building background knowledge of weather terminology to determine if the phenomenon could be natural
- ✓ Students will understand the primary characteristics used to describe weather
- ✓ Students will use weather data to determine if the phenomenon is natural or man-made

Activity 3 (Explore): Pollution, Power Plants, and People
Timing: 60 minutes
Purpose: Determining whether the phenomenon may be man-made by looking at how humans impact the environment.
- ✓ Students will use maps to identify connections among air quality, population, and electricity production

Activity 4 (Explain): The Criteria Air Pollutants
Timing: 45-60 minutes
Purpose: Building understanding of different kinds of air pollution and their sources, including the 6 criteria pollutants, in order to identify the pollutant causing the phenomenon
- ✓ Students will define air pollution
- ✓ Students will know there are different kinds of air pollution, and some are more important for us to consider
- ✓ Students will identify the pollutant that caused the Code Red Day in DC

Activity 5 (Explain): O_3, Oh My! Getting to Know Ozone
Timing: 30 minutes
Purpose: Understanding ozone and its role in air quality
- ✓ Students will understand what ozone is from both a general and chemical perspective
- ✓ Students will understand the different between beneficial (stratospheric) and harmful (tropospheric) ozone

Activity 6 (Explore): Air Quality in the DC/Baltimore Region
Timing: 2 class periods
Purpose: Understanding the Air Quality Index (AQI) and using it to explore air pollution and air quality issues at the local level

- ✓ Students will learn to interpret the Air Quality Index (AQI)
- ✓ Students will research current and historical AQI data from the DC/ Baltimore area
- ✓ Students will identify the major air pollutants in the DC/Baltimore area and analyze data to show how they have changed over time

Activity 7 (Explore): Air Pollution Trends and the Clean Air Act
Timing: 1-2 class periods
Purpose: Understanding how humans can have a positive impact on air quality by investigating how air quality has changed since the Clean Air Act

- ✓ Students will interpret graphs to determine how air quality in the US has changed over time
- ✓ Students will use the Clean Air Act to discuss whether humans have a positive or negative impact on the planet

Activity 8 (Elaborate): Smog City: How Weather Affects Air Quality
Timing: 45 minutes
Purpose: Determining how air quality and weather interact, along with how humans affect air quality

- ✓ Students will understand how different weather conditions affect AQI
- ✓ Students will understand how emissions from various sources and population affect AQI

Activity 9 (Elaborate): Making an Air Quality Prediction
Timing: 45-60 minutes
Purpose: Appplying knowledge about air quality and weather to a real world situation

- ✓ Students will be able to make an AQI prediction using data from a variety of information sources including weather conditions

Activity 10 (Evaluate): Creating an Air Quality Report
Timing: variable, minimum two class periods
Purpose: Showing student understanding of module objectives

- ✓ Students will create an air quality report based on an AQI forecast and weather conditions

Module Materials

Activity 1 (Engage): What's That in the Sky?

- ❒ Handouts: I See, I Think I Wonder, Investigation Tracker
- ❒ Materials needed: Computer & projector
- ❒ Optional materials: Air Quality Champion Interview

Activity 2 (Explain): What is Weather?

- ❒ Handouts: Visual vocabulary sheets
- ❒ Materials needed: Computer & projector, Resources for students to research weather terms (student computers with internet access, textbooks, library books, etc.)
- ❒ Optional materials: Chart paper & markers, I Have, Who Has game cards

Activity 3 (Explore): Pollution, Power Plants, and People

- ❒ Handouts: Human Activities and the Earth
- ❒ Materials needed: Computer & projector
- ❒ Optional materials: Student computers, chart paper

Activity 4 (Explain): The Criteria Air Pollutants

- ❒ Handouts: The Criteria Air Pollutants (foldable or regular)
- ❒ Materials needed: Computer & projector, air pollution information stations, sources of air pollution signs
- ❒ Optional materials: scissors

Activity 5 (Explain): O_3, Oh My! Getting to Know Ozone

- ❒ Materials provided: Ozone: Good Up High, Bad Nearby (graphic organizer)
- ❒ Materials needed: Computer & projector, speakers
- ❒ Optional materials: Student computers

Activity 6 (Explore): Air Quality in the DC/Baltimore Region

- ❒ Handouts: Air Quality Index reading, Historical AQI Data Investigation, AQI Through the Years
- ❒ Materials needed: Computer & projector, "The Air Quality Today in <blank> is" posters
- ❒ Optional materials: Student computers (highly recommended), graph paper

Activity 7 (Explore): Air Pollution Trends and the Clean Air Act

- ❒ Handouts: Air Pollution Summary
- ❒ Materials needed: Computer & projector, speakers, Pollutant Trends Graphs
- ❒ Optional materials: Student computers (highly recommended), How Much Pollution is Too Much (handout)

Activity 8 (Elaborate): Smog City: How Weather Affects Air Quality

- ❒ Handouts: Save Smog City From Ozone
- ❒ Materials needed: Computer & projector
- ❒ Optional materials: Student computers (highly recommended)

Activity 9 (Elaborate): Making an Air Quality Prediction

- ❒ Handouts: AQI prediction guide
- ❒ Materials needed: Computer & projector
- ❒ Optional materials: Student computers (highly recommended)

Activity 10 (Evaluate): Creating an Air Quality Report

- ❒ Handouts: Project guidelines, Grading rubric
- ❒ Materials needed: n/a
- ❒ Optional materials: Student computers (highly recommended), video recording devices

Ozone

Ozone is a gas found in different parts of the atmosphere. Ozone in the upper atmosphere, or stratosphere, helps protect the Earth from the sun's harmful rays. In the lowest level of the atmosphere, the troposphere, exposure to ozone also can be harmful to both human health and some plants. For this reason, ozone is often described as being "good up high and bad nearby" (U.S. EPA, 2003a). Most ground-level ozone forms in the air from chemical reactions involving nitrogen oxides (NOx), volatile organic compounds (VOCs), and sunlight. Ozone levels are typically highest during the afternoon hours of the summer months, when the influence of direct sunlight is the greatest. These highest levels occur during what is known as the "ozone season," which includes at least the spring and summer months but whose time frame varies by state (U.S. EPA, 2003b).

Variations in weather conditions play an important role in determining ozone levels. Daily temperatures, relative humidity, and wind speed can affect ozone levels. In general, warm dry weather is more conducive to ozone formation than cool wet weather. Wind can affect both the location and concentration of ozone pollution. NOx and VOC emissions can travel hundreds of miles on air currents, forming ozone far from the original emissions sources. Ozone also can travel long distances, affecting areas far downwind. High winds tend to disperse pollutants and can dilute ozone concentrations. However, stagnant conditions or light winds allow pollution levels to build up and become more concentrated.

Inhalation exposure to ozone can cause many harmful health effects. Examples include respiratory effects, such as difficulty breathing, coughing, and airway inflammation. For people with lung diseases such as asthma, emphysema, and chronic obstructive pulmonary disease (COPD), these effects can lead to emergency room visits and hospital admissions. Ozone exposure also is likely to cause premature death from lung or heart diseases. In addition, evidence indicates that long-term ozone exposure may lead to the development of asthma and permanent lung damage (U.S. EPA, 2013).

People most at risk from breathing air containing ozone include people with asthma, children, older adults, and people who are active outdoors, especially outdoor workers. In addition, people with certain genetic characteristics, and people with reduced intake of certain nutrients, such as vitamins C and E, are at greater risk from ozone exposure. Research also indicates people with certain health conditions, such as obesity or diabetes, may be at increased risk of ozone-related health effects. Elevated concentrations of ozone can also affect some vegetation and ecosystems (U.S. EPA, 2013).

Trends in Ozone Levels in the US

Between the 1978-1980 and 2014-2016 averaging periods, ambient ozone concentrations decreased significantly. The 8-hour ozone levels in 2014-2016 were the second lowest on record. However, despite reductions in ambient concentrations of ozone over the past quarter century, ozone concentrations above the health-based air quality standards remain one of the most persistent air pollution problems in many parts of the U.S.

Adapted from: *Ozone Concentrations*, Report on the Environment, US EPA,
https://cfpub.epa.gov/roe/indicator_pdf.cfm?i=8

AQI Basics

What is the U.S. Air Quality Index (AQI)?
The U.S. AQI is EPA's index for reporting air quality.

How does the AQI work?
Think of the AQI as a yardstick that runs from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 or below represents good air quality, while an AQI value over 300 represents hazardous air quality.

For each pollutant an AQI value of 100 generally corresponds to a concentration equal to the level of the short-term national ambient air quality standard (NAAQS) for protection of public health. AQI values at or below 100 are generally thought of as satisfactory. When AQI values are above 100, air quality is unhealthy: at first for certain sensitive groups of people, then for everyone as AQI values get higher.

The AQI is divided into six categories. Each category corresponds to a different level of health concern. Each category also has a specific color. The color makes it easy for people to quickly determine whether air quality is reaching unhealthy levels in their communities.

AQI Basics for Ozone and Particle Pollution

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

Five Major Pollutants
EPA establishes an AQI for five major air pollutants regulated by the Clean Air Act. Each of these pollutants has a national air quality standard set by EPA to protect public health:

- ground-level ozone
- particle pollution (also known as particulate matter, including PM2.5 and PM10)
- carbon monoxide
- sulfur dioxide
- nitrogen dioxide

Adapted from *AQI Basics*, Air Now. https://www.airnow.gov/aqi/aqi-basics/

Quantities and the Earth's Atmosphere

The vast majority of Earth's atmosphere is made up of just two gases: nitrogen or N_2 (78%) and oxygen or O_2 (21%). Trace gases such as argon (1%), water vapor (1%), carbon dioxide (0.04%), and others are also present in very small amounts. Pollutants may be harmful at even smaller amounts. To describe these very small amounts of gases, scientists use the measures parts per million (ppm) and parts per billion (ppb). One percent is equal to one part per hundred or 10,000 parts per million. Similarly, one part per million equals 0.0001%.

$$1\% = \frac{1}{100} \times \frac{10{,}000}{10{,}000} = \frac{10{,}000}{1{,}000{,}000}$$ 1% = 10,000 ppm

$$\frac{1}{1{,}000{,}000} \times \frac{0.0001}{0.0001} = \frac{0.0001}{100} = 0.0001\%$$ 1 ppm = 0.0001%

Expressed using ppm, the major components of Earth's atmosphere are:

- Nitrogen: 780,800 ppm (78.08%)
- Oxygen: 209,500 ppm (20.95%)
- Argon: 9,340 ppm (0.93%)
- Water vapor: ~10,000 ppm (~1%)
- Carbon dioxide: 410 ppm (0.041%)

Additional sources of background information for teachers:

The Clean Air Act:

- Plain English Guide to the Clean Air Act: https://www.epa.gov/sites/production/files/2015-08/documents/peg.pdf

Acronyms

- NAAQS: National Ambient Air Quality Standards – the is the "safe" level of each pollutant.

Activity 1 (Engage): What's That in the Sky?

Activity summary: Students are introduced to the anchor phenomenon for the unit by looking at a picture of a city at two different times: half of the picture shows the city hazy with smog, and the other half is clear. Students consider what could be causing this unusual phenomenon.

<u>Standards Connection</u>
DCI: ESS 3.C – Human Impacts on Earth's Systems

Warmup: What is it like outside today? Use descriptive language to provide as many details as possible.

- Use this warmup as a way to get students thinking about how they would describe current weather conditions. They will almost certainly not describe the air quality, but they may say things like "it is clear" or "it is cloudy." Tell students to keep these words in mind for later in the activity.

1. **Frame the activity:** Tell students that they are starting a new investigation today. For this investigation, they are going to take on the role of meteorologists (weather scientists) to study a strange thing that happened in the city (or a nearby city) a few summers ago. It will be up to them to use their scientific skills to figure out what happened. Then they will need to use their weather forecasting skills to figure out if the strange thing is going to happen again, and what to people about it.

Air Quality Champion

Amelia Draper is the StormTeam 4 meteorologist on NBC in Washington, D.C. As the station scientist, she is responsible for informing people about the weather and the air quality. Read more about Amelia and her story at the end of the module.

2. **Introduce the phenomenon:** Hand out the I See, I Think, I Wonder sheets to students. Show students the picture on the next page and tell them that this picture shows a similar situation to the one that happened nearby, but in a different city. Start by having students write down what they **see** in the picture in the top row of their paper. Encourage them to write about the whole picture, and only write things they can see directly.

ACTIVITY DETAILS

Time: 30-45 minutes

Objectives
- ✓ Students will make observations and hypotheses, and ask questions to better understand the anchor phenomenon

Materials
- ✓ Computer & projector

Handouts
- ✓ I See, I Think, I Wonder
- ✓ Investigation Tracker
- ✓ Air Quality Champion interview (optional)

Personal connection (recommended)
- ✓ Sometime during the module, have students read the interview with this module's Air Quality Champion to help them understand the people who keep us safe from air pollution and the kinds of work that they do.

TEACHER NOTES

The phenomenon

✓ This image shows the city of Tieling, China, at two different times during a 10-day period in 2019. The left side shows the city shrouded in smog (ground-level ozone), while the right side shows the city on a clear day. Moderate winds and cooler temperatures can keep ozone levels low, so it is not unusual to have very different levels of smog during a relatively short period of time. Smog is still a problem in many US cities, although things have improved. You can find historical photos of Baltimore air pollution here: http://darkroom.baltimoresun.com/2017/04/from-the-vault-air-pollution-baltimore/#1 and a photo of DC here: https://www.washingtonpost.com/lifestyle/kidspost/good-day-to-play-outside-learn-about-air-pollution-to-find-out/2015/08/03/3708e168-30a5-11e5-97ae-30a30cca95d7_story.html If you show any of these photos to students, try to keep the pollution connection secret until later in the module.

Credit: Tomskyhaha / CC BY-SA

Students should recognize the very hazy sky and buildings on the left side of the picture and the blue sky and clear buildings on the right side of the picture. They may also note the clouds on one side and not the other, and the fact that there are buildings that go across the picture. After students have had some time to write, have them turn to a partner to share what they wrote. Encourage them to add things their partner noticed to their sheets.

Next, have students write down what they **think** is going on in this image in the middle row of their paper. When they've had a chance to write some ideas, have them share with a partner again. They may have a variety of ideas, such as:

- the picture was altered (ex. colored)
- the image shows two different places
- the image shows the same place at different times
- the left side shows the city on a foggy day and the right side shows the city on a clear day

Finally, have students write down what they **wonder** about this picture using questions in the bottom row, and again have them share with their partner. Things they may consider:

- Has this photo been altered in any way?
- Why is the sky so foggy/cloudy on the left side?
- Is this all one city?
- Why does the picture look so different on each side?
- Where was this photo taken?

Once students have had a chance to share with their partner, give them a chance to share some of the things they saw, thought, and wondered about the picture with the whole group. Acknowledge students' answers and help them make connections with one another, but do not give away any information about the picture.

3. **What could be causing this?** Ask students what they think could be causing the city to look this way. Hand out the Investigation Tracker sheet to students, and have them brainstorm some ideas with a partner in the first row (Activity 1). If students struggle to come up with ideas, use questions to help them brainstorm. Possible answers:
    - It is smoky because of a fire
    - It is foggy
    - It is snowing
    - There is something else falling from the sky (ex. volcanic ash)
    - The air is polluted

   After they have had time to come up with some ideas, have pairs share with the whole group. Record students' ideas on chart paper that you can put up and save for the rest of the module. (Note: it will be helpful for Activity 2 if at least one student says that they think it is fog). Have students copy any of their peers' ideas that they like into the first row. Tell students that they will be using this sheet to track their learning as they complete their investigation.

4. **July 9, 2018:** Tell students that a similar thing to what they see in left side of the picture happened in the DC area on July 9, 2018. Show them the picture in this link: https://tinyurl.com/DCCodeRed, which shows the White House under a hazy sky (note: it is not nearly as pronounced as in the earlier picture). Tell them that because of this haze, meteorologists called it a "Code Red Day." Have students imagine that they were in the city that day. What do they think it would have been like? Do they think it would be hot or cold? Rainy or cloudy? Do you think it would be okay to go outside and play on a day like that? Give students a chance to share their ideas about what they think it would have been like. Have them consider how they described what it is like outside today during their warmup, and have them compare this to their description what it would be like on that day in July.

   Tell students that during the next few activities, they are going to study this strange thing to see if they can figure out what is going on and whether it is a problem for people.

TEACHER NOTES

Modification

✓ During the I see, I think, I wonder, have students share whole group at the end of each section instead of only once at the end.

Teacher Tip

✓ The Investigation Tracker is designed to help students with sensemaking about big concepts from the module. Try to prevent students from just copying down what you write by always having them write first and then adding to their ideas.

Connection to Module 1

✓ If you have done Module 1 with students, they may already be making connections here to ozone pollution. This will accelerate their understanding of the phenomenon, but it won't affect the rest of the module.

TEACHER NOTES

Current events

- ✓ For some fascinating images of how the coronavirus lockdowns have altered the amount of smog in major cities around the world, check out this article from Insider: https://tinyurl.com/LockdownSmog

5. **Formative assessment:** Have students go back to the "I See, I Think, I Wonder" side of their sheets, and identify what big questions they need to answer to understand what's going on in the picture. Have them put a star or highlight those questions. They may also need to add a question based on what they've learned, which they can write in the "Big questions" space. Good big questions might be:
   - **What is causing the sky to look hazy in the picture?**
   - **What was the weather like that day?**
   - **Is there something in the air that is making the picture look that way?**

   Use students' I See, I Think, I Wonder sheets as a formative assessment, either by collecting them to evaluate students' thinking process, or by circulating at the end of class and taking note of what they have written.

Name__________________________________

STUDENT HANDOUT

I See, I Think, I Wonder…

I see…
I think…
I wonder…
Big questions:

STUDENT HANDOUT

Investigation Tracker

What have I learned about what happened in Washington, D.C. on July 9th, 2018?	
Activity 1	
Activity 2	
Activity 3	
Activity 4	

Activity 5	
Activity 6	
Activity 7	
Activity 8	

TEACHER GUIDE

Investigation Tracker

What have I learned about what happened in Washington, D.C. on July 9th, 2018?	
Activity 1	It could be… • It is smoky because of a fire • It is foggy • It is snowing • There is something else falling from the sky (ex. volcanic ash) • The air is polluted
Activity 2	• The haze is not fog because the weather conditions were not right to make fog • It was unlikely to be natural, because there are no other good natural explanations • It is likely to be man-made
Activity 3	• The haze could be caused by humans because humans can affect the atmosphere by creating air pollution • It could be air pollution from things like coal power plants. • There are some power plants near DC, but not a lot • There are a lot of people in the DC area
Activity 4	• The haze is caused by ground-level ozone pollution (smog) • Ozone forms when certain air pollution is released from cars, power plants, and industrial facilities. These pollutants react with heat and sunlight, which makes ground level ozone.

Activity 5	• There are two kinds of ozone: ground-level ozone and stratospheric ozone • Ground-level ozone (tropospheric) is a harmful pollutant that can hurt people's lungs and damage crops • Stratospheric ozone (in the ozone layer) protects Earth from harmful radiation • Ground-level ozone is formed when certain kinds of air pollution react with heat and sunlight • You can prevent ozone from forming by using less electricity and driving less
Activity 6	• Air quality is measured using a scale call the Air Quality Index (AQI) • The main air pollutants in the DC-Baltimore area are particulate matter (PM) and ozone. • Air quality in the DC-Baltimore area is improving
Activity 7	• Air quality in the United States has improved a lot since 1980. • The Clean Air Act was a very important law that helped the US to clean up the air • People can have positive and negative impacts on the environment by polluting, or by working to stop pollution
Activity 8	• Air pollution (especially ozone) is strongly affected by the weather • Weather conditions like clear sunny skies and low wind are more likely to result in a bad ozone day • Rain can "wash" pollution out of the air resulting in less ozone. • Large human populations can result in more emissions and worse air quality if they don't do something to prevent it

Activity 2 (Explain): What is Weather?

ACTIVITY DETAILS

Time: 1-2 class periods

Objectives

- ✓ Students will understand the primary characteristics used to describe weather
- ✓ Students will use weather data to determine if the phenomenon is natural or man-made

Materials

- ✓ Computer & projector
- ✓ Resources for students to research weather terms (computers & internet, textbooks, library books, etc.)
- ✓ Markers (if students are using chart paper)
- ✓ I Have, Who Has cards (optional) – printed and cut

Handouts

- ✓ Visual vocabulary sheets (enough based on how many each student will do) OR chart paper for each entry

Activity summary: In this activity, students learn to interpret a weather forecast by learning about the different terms and units involved in weather such as temperature, humidity, wind, precipitation, sky condition, and air pressure. They use this information to determine if the hazy sky in the photograph could be naturally occurring fog.

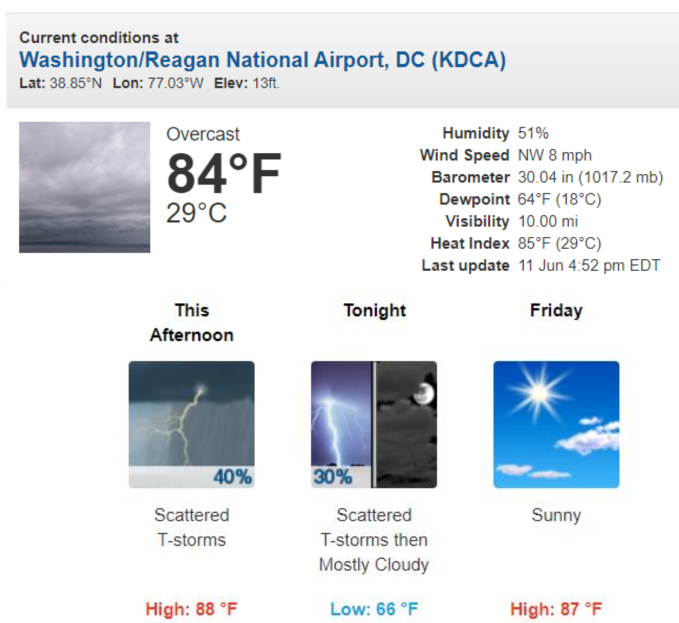
Standards Connection

DCI: ESS 2.D Weather & Climate
SEP: Obtaining, evaluating, and communicating information
CCC: Systems & System Models

Important Note about this Activity

This activity provides a brief background in weather terminology and concepts to allow students to engage with the activities that follow. Ideally, students will have already explored these ideas in a prior unit, and this lesson can serve more as a refresher than new learning. If students have already studied weather before, you may choose to skip the first part of this activity, but make sure to do the "Return to the Phenomenon" section (step 5).

Warmup: Show students a current weather forecast like the one below from weather.gov and ask what information it provides (temperature, humidity, wind, precipitation, sky condition, dew point, etc.) Based on this information, have them write a definition for weather that uses some of these terms.



Have students share their definitions with a partner or group, and come to a consensus for a definition of weather. Their definitions do not need to be precise – you will come back to this question later. A possible student definition might be "Weather is what it is like outside: for example, what the temperature is and whether it is precipitating or not."

1. **Frame the activity:** Point out the chart paper list of students' ideas of what could be causing the haziness in Washington DC like in the left side of the image. Have them identify which causes are natural, and which would be man-made. For example, if it is caused by a fire/smoke, then it is likely man-made, and if it is fog or snow, it is natural. Once they have divided up the list, tell them that today they are going to investigate the "natural" list to see if any of these could be the cause. They will do this by learning about weather in order to determine how things like fog form.

2. **Parts of a Weather Model:** Remind students' that for this investigation they are taking on the role of meteorologists. Meteorologists study how weather works by building weather models. A weather model is not like a model of the solar system. It is a computer program based on math and science that takes information about the current weather, and uses it to make a prediction about what the weather will be. In order for them to understand whether the haze could be natural, they need to understand the parts of a weather model. Ask students what kinds of information they think needs to go into a weather model. Write students' responses to this question on the board to make a list of inputs to the weather model. Remind them of answers to their warm-up, and use additional follow-up questions as necessary.
    - Key inputs: temperature, wind speed/direction, time of year (season), humidity, precipitation, location, dew point

3. **Visual Vocabulary:** Tell students that in order to use these scientific terms to make predictions, it's important to make sure everyone has a common understanding of what they mean. To help with this, they are going to make a visual glossary of terms. Show students the example of the glossary entry for temperature below, and review the parts: the term, the definition, a picture to illustrate the term, an example of how it is used, the measuring tool used to measure it, and the units or scale that go with it.

TEACHER NOTES

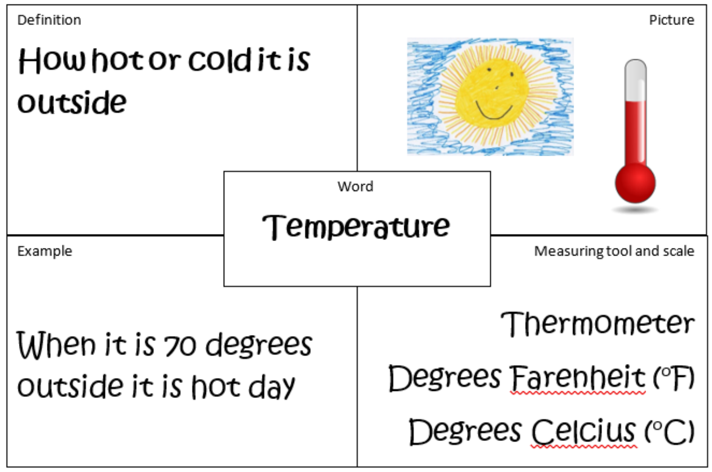
Differentiation

- ✓ You can have all students do all the terms, divide up the terms and have each student do one or divide students into groups and have each group do all the terms. Suggest more complex terms (ex. temperature inversion) for more advanced students

Modification

- ✓ Instead of having students make the glossary on standard-sized paper, have groups each make an entry on chart paper to put up around the room. Have each group present their poster before they put it up.

TEACHER NOTES



Identify what terms you want students to include in their glossary.

- Required: temperature, precipitation, humidity, wind, sky condition (cloudy, sunny, etc.), dew point
- Optional: air pressure, season, temperature inversion (see: http://ffden-2.phys.uaf.edu/212_spring2007.web.dir/Amber_Smith/Effects_of_Inversions.htm)

You can divide up the terms so that each student has a few, or have all students do all the terms. Once students understand the directions, provide them with the resources to do their research. Age-appropriate books on weather, and weather websites such as weatherwhizkids.com are good choices.

After students have created their glossary terms, make sure they have had a chance to share with others so that all students have interacted with all the terms.

4. **I Have, Who Has (optional).** Tell students that you are going to play a game to help them remember the weather terms you learned about today. Pass out the "I have, who has?" cards (make sure each student has at least one card, and make sure all the cards have been passed out. Have students work in pairs if you have more students than cards). Go over the directions with students:
    - One student will begin by reading the "who has" portion of their card.
    - The student who has the "answer" to that card will say, "I have <the answer>. They will then read the "who has" portion of their card
    - Continue until all the cards have been read, and you've gotten back to the beginning of the circle.

Differentiation

✓ For the first round of "I have, who has" pass the cards out in order so that students can go around the class as a review of the terms. Then recollect them and mix them up.

Modification

✓ The "I have, who has" template is easy to edit. Add or remove the "I have" and "Who has" entries for any terms, and adjust the table. Just make sure that the last card connects back to the first one.

While students are playing, listen for any errors, and support students in getting back on track if they make a mistake or get stuck. Students may have slightly different definitions based on their research, so it's important to follow along. Students should also follow along to help each other.

For more information on how to play, watch this video: https://www.youtube.com/watch?v=- v4JDPN8wec

5. **Return to the phenomenon:** Go back to the list of "natural" possibilities for what is causing the haziness in the photos. Some things students might have suggested for natural are snow, fog, and volcanic ash. Ask students what weather information they would need to know to determine if any of these are possibilities (only use the ones they suggested).
    - Snow: temperature and precipitation
    - Fog: temperature and dew point (students will likely not know this, so you can help them or look it up together)
    - Volcanic ash: (in the event students bring this up, you can ask students if there are any volcanoes in the DC area)

Tell students that in order to find out what Washington DC was like on that July 9, 2018, they can look up historical weather information online. Go to: https://www.wunderground.com/history/daily/us/dc/KDCA/date/2018-7-9 and display the weather information for DC on July 9, 2018 (the "daily observations" section at the bottom has all the information they need).

Have students consider whether the conditions are right for snow. They may already have realized that there wouldn't be any snow in July, but it is still useful to see that the low temperature was 65°F and there was no precipitation, so it couldn't be snow.

Next have students think about fog. If you haven't already looked this up together, then make sure students know the requirements for fog to form: the temperature and the dew point need to be the same or very close (within a few degrees). Have students look at the data to determine whether fog could have formed that day. Have them turn to a partner and decide what they think.

After a short time, have students share their analysis. They should recognize:

- The dew point in DC on 7/9/18 ranged from 51°F - 59°F.
- The low for the day was 65°F.
- The closest the temperature and dew point ever got together was 10°F at 5:52 am.
- Based on this information, fog would not have formed because the temperature and dew point never got close enough together.

TEACHER NOTES

Tech integration

✓ Websites such as quizlet are another great way to help students develop understanding of the weather vocabulary

Modification

✓ You may want to print out this weather information in advance so students can look at it on their own.

TEACHER NOTES

Looking ahead

✓ Students will use these weather terms in later activities, so you may want to have them study the terms for homework or review them before the next activity.

Have students go back to their Investigation Tracker from Activity 1 and add new information in the space for Activity 2 based on what they learned today about the phenomenon. The most important information they learned is:

- The haze is not fog because the weather conditions were not right to make fog
- It was unlikely to be natural, because there are no other good natural explanations
- Therefore, it is likely to be man-made

6. **Defining weather:** Have students go back to their original definition of weather, and see if there is anything they want to add or clarify. Their definition should recognize that weather is a description of a variety of atmospheric conditions (temperature, precipitation, dew point, humidity, pressure, etc.) and that it refers to a short period of time because the weather can change quickly (as opposed to climate, which may only change over long spans of time). Either as a class or in their groups, reach a consensus definition. Then write the definition (or group definitions) in big letters on a piece of paper and post it prominently in the classroom.

7. **Formative assessment**. Have students Interpret a current weather forecast based upon the content that they learned today.
   - Option 1: Show a video weather forecast, and have students identify what each of the terms are and how they are used. (ex. temperature, humidity, cloud cover, etc.)
   - Option 2: Show a weather forecast from a website or newspaper and have students identify what each of the terms are and how they are used.

Definition	Picture
Example	Measuring Tool & Scale

Word

TEACHER GUIDE

I Have, Who Has Weather Terms

Answer Guide

	I have…	Who has…
1	Temperature	The units for wind speed
2	Knots, meters per second, or miles per hour	The tool for measuring humidity
3	Hygrometer	Moving air
4	Wind	The weight of air pressing down
5	Air pressure	Rain, snow, sleet, or hail
6	Precipitation	The scale and units for temperature
7	Degrees Fahrenheit or degrees Celsius	How cloudy the sky is
8	Sky condition	The tool to measure wind speed
9	Anemometer	The units for air pressure
10	Inches or mm of mercury or psi	The tool to measure temperature
11	Thermometer	The tool to measure amount of rain
12	Rain gauge	Winter, spring, summer, or fall
13	Seasons	The tool to measure wind direction
14	Wind vane or weather vane	The amount of water vapor in the air
15	Humidity	An example of sky condition
16	Partly cloudy	An example of temperature
17	75 degrees Fahrenheit	The tool to measure air pressure
18	Barometer	An example of relative humidity
19	48%	An example of wind direction
20	Northwest	The temperature at which water condenses
21	Dew Point	How hot or cold it is

To prepare for the game, print out the cards on the following pages and cut them along the dotted lines.

I have temperature Who has the units for wind speed?	I have knots, meters per second, or miles per hour. Who has the tool for measuring humidity?
I have hygrometer. Who has moving air?	I have wind. Who has the weight of air pressing down?
I have air pressure. Who has rain, snow, sleet, or hail?	I have precipitation. Who has the scale and units for temperature?
I have degrees Fahrenheit or degrees Celsius. Who has how cloudy the sky is?	I have a sky condition. Who has the tool to measure wind speed?
I have anemometer. Who has the units for air pressure?	I have inches or millimeters of mercury or pounds per square inch (psi). Who has the tool to measure temperature?
I have thermometer. Who has the tool to measure amount of rain?	I have rain gauge. Who has winter, spring, summer, and fall?

I have seasons. Who has the tool to measure wind direction?	I have wind vane or weather vane. Who has the amount of water vapor in the air?
I have humidity. Who has an example of sky condition?	I have partly cloudy. Who has an example of temperature?
I have 75 degrees Fahrenheit. Who has the tool to measure air pressure?	I have barometer. Who has an example of humidity?
I have 48%. Who has an example of wind direction?	I have northwest. Who has the temperature at which water condenses.
I have dew point. Who has how hot or cold it is?	

Activity 3 (Explore): Pollution, Power Plants, and People

Activity summary: In this activity, students look at maps of air pollution sources, air quality, and population to see how humans impact the environment. They will use this information to determine if the haze in their phenomenon photographs could be man-made.

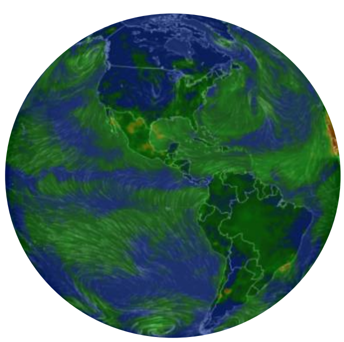
Standards Connection
DCI: ESS 3.C – Human Impacts on Earth's Systems
SEP: Obtaining, Evaluating, and Communicating Information
CCC: Patterns

Warmup: What kinds of things do people do that affect the Earth? For example, we cut down trees to make room for farming. What other things do humans do that change the planet?

- Students answers may include: we build houses and other buildings, we pave over the grass, we put dams on rivers, we put pollution into the air and the water, we dig resources out of the ground, etc.
- Use this warmup to activate student prior knowledge on human activities that might affect the planet (and potentially cause our phenomenon)

1. **Frame the activity:** Remind students that in the last activity, they decided that the haze in the pictures is unlikely to be natural. That means that it's probably man made. But they still don't know what kind of activities could create a haze like that. In order to investigate how humans affect the planet, they're going to look at a series of maps to look for patterns in human activities and how they affect the atmosphere. Hand out the Air

2. **The World Air Quality Globe & Map.** Display the live world air quality globe for all students to see: www.iqair.com/earth, but don't tell them what it is.



Rotate the globe to show students different parts of the world and zoom in to different places. Ask students what they think the globe shows. Some may say it has something to do with temperature, weather or air pollution (if they've done Module 1).

ACTIVITY DETAILS

Time: 45-60 minutes

Objectives
- ✓ Students will use maps to identify connections among air quality, population, and electricity production

Materials
- ✓ Computer & projector
- ✓ Chart paper (for research sources list)
- ✓ Student computers (optional)

Handouts
- ✓ Humans Activities and the Earth

Other Air Quality Maps
- ✓ The World Air Quality Index project has another good world air quality map. It has more data and more options, but is somewhat less visually appealing. You can find that map at: http://www.waqi.info/

Tech integration
- ✓ If student computers are available, you can have students look at these maps on their own devices.

TEACHER NOTES

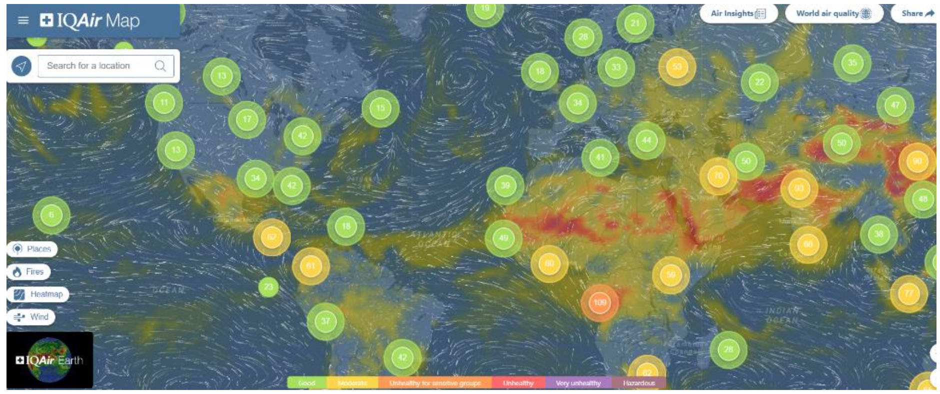
Teacher Tip

✓ The IQAir map focuses on particulate matter pollution (PM). For ozone information, use the maps at waqi.info and choose ozone from the pollutant menu

Cultural awareness

✓ Different parts of the world are in different stages of development, and therefore are in different stages of pollution control. Keep this in mind when talking about parts of the world, especially if you have students from these regions. Having poor air quality is a challenge all developing nations have faced; it does not make them bad countries.

Next go to the World Air Quality map: www.iqair.com/air-quality-map.



Have students jot down some observations of what they see on the map on their handouts. Key observations:

- There are a lot of data points/numbers
- The data points have different colors
- Something is flowing around (if you have wind map on)
- The colors tend to be grouped together

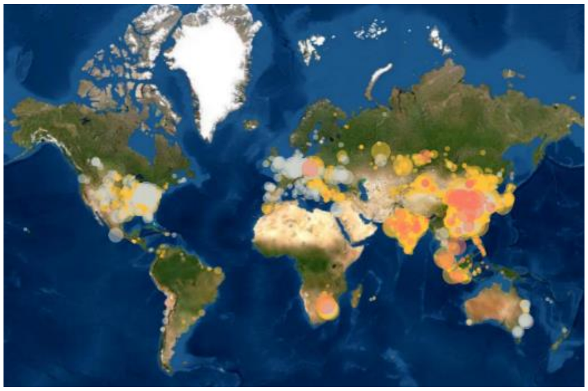
Ask the students why they think the data points are in different colors. Students may look at the scale at the bottom right, or they may think that green is good and red is bad because many scales use this coding.

If students haven't made the connection yet, tell them that this is a map of air pollution. Point out the scale and make sure students understand the scale in general (low numbers and green are good; high numbers and red/purple are bad). Have them add this information on their handouts.

3. **Identifying pollution sources:** Ask students what patterns they see in where the good and bad air quality is around the world. They should see that there is more air pollution in certain parts of the world compared to others. Have them write down what parts of the world have more air pollution (ex. China, India, and parts of Africa), and what parts have less (North and South America and Europe). Help students identify geographical areas and countries to use in their description. You may also need to zoom in to certain parts of the map to make this clearer.

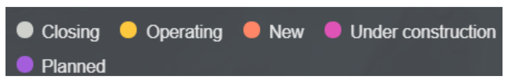
Have students turn and talk to a partner about why the air pollution might be better or worse in different parts of the world. After they've discussed, have groups share their hypotheses, but don't tell them whether their answers are correct or not. Use probing questions to help clarify their thinking.

Next, show students the map of world coal power plants from Carbon Brief: https://www.carbonbrief.org/mapped-worlds-coal-power-plants. Have students look at the scale to understand what the different size circles represent and the different colors. Have them use this information to answer the questions on their sheet.



Size of circles = capacity of power plant (bigger circle = more power)

Color = stage of operation



Next have students look at where power plants are opening vs. closing and ask them what they notice. Then have them look at the size of the power plants and ask them what they notice. Key takeaways:

- Most new and big coal plants are in India and China
- Many other parts of the world are closing their coal plants

4. **Identifying large human populations:** Show students the map of world population (next page) and make sure they understand what the colors represent. https://sedac.ciesin.columbia.edu/data/set/gpw-v4-population-density-rev11/maps

TEACHER NOTES

Personal connection

- ✓ Have students think about what it might be like to be a middle school student in these different places. Do they think that it would affect their health? How would they feel to live in a place that had high levels of air pollution?

Air pollution in Africa

- ✓ North Africa and sub-Saharan Africa have significant air pollution but few large power plants. Much of this pollution comes from Saharan dust storms, household fuel burning, and transportation. The large population sizes of sub-Saharan African countries result in significant burning of wood, charcoal, and kerosene for fuel. In other words, these countries burn fuel much like other countries, it just happens locally instead of in large power plants.

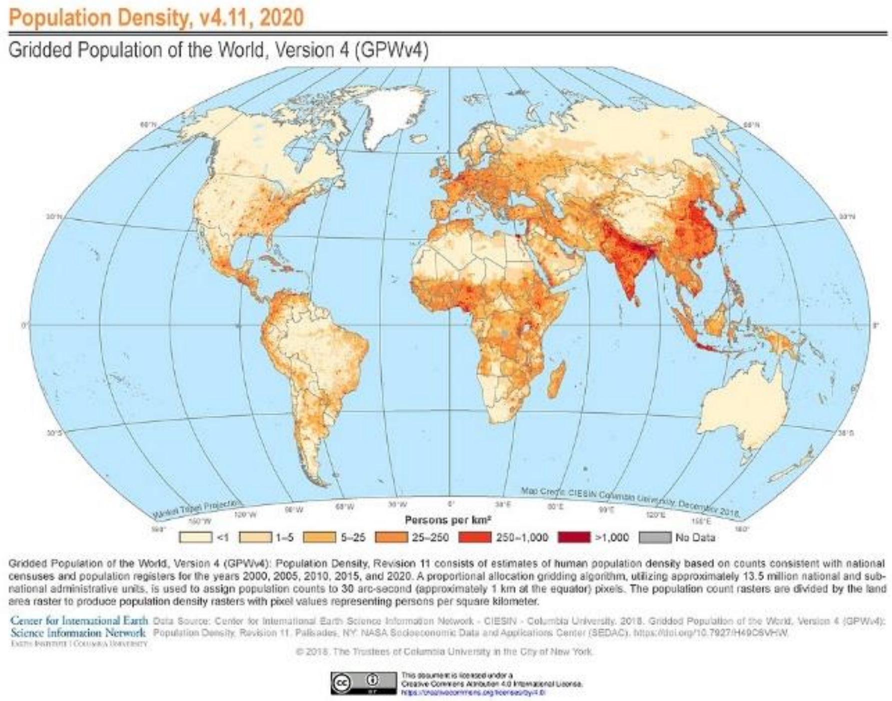
Teacher Tip

- ✓ If you follow the link provided, you will need to download the world population map needs before it can be shown

TEACHER NOTES

Math connection

- ✓ This map shows population density in persons/km², not raw population. If you have time, write the units for population density and take a moment to review with students what the unit means and how it can be used to show where there are large concentrations of people in one place.



Have students look at the scale and identify what the colors mean (lighter colors = less population, darker colors = more population). Have them answer the questions about the scale on their handouts. Then ask what they notice about the world population map. Key takeaways:

- There are large populations of people in India & China, sub-Saharan Africa, Europe, the eastern US, and parts of central America.

Have students write down on their handouts where there are large populations of people.

5. **Putting it All Together**: Tell students that in order to think about how humans affect the Earth, they need to look for patterns across the three different maps they looked at. In small groups, have them look back at their notes and identify and patterns (similarities) that they see. Give students time to work. While they are talking, circulate and ask questions to help push their thinking. The key point that students should recognize:

    - In general, places where there are a lot of people and a lot of power plants, there is bad air pollution.

    After small groups have had a chance to talk, bring the whole group together and have them summarize what they noticed.

    This concept – that high population and power generation often results in air pollution – is an incredibly important point for students to grasp, so make sure that they understand before moving on.

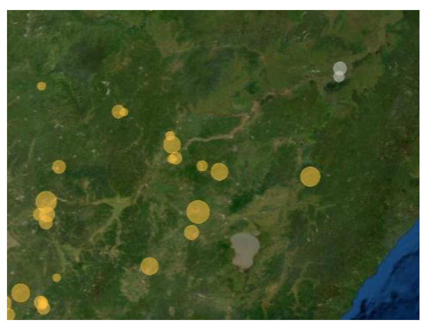
Use follow up questions to push their thinking on why the air pollution is worse in places where there are more people and more power plants. Students may not understand that coal plants emit large amounts of air pollution, and high population means other source of pollution like transportation, fires, etc. This connection will be much more explicit in the next activity, but get their minds thinking about this in the meantime.

Have students write a short summary about this pattern in the space on their handout.

Ask students if this pattern is true everywhere in the world. They should be able to recognize that in some parts of the world, there are higher populations (like Europe) that don't have a lot of air pollution. The US has coal power plants and a relatively high number of people, but not bad air pollution. Ask students why they think this is (there is a space for them to write some ideas on their handouts). As with the sources of air pollution, students likely will not know for certain, but tell them that they will try to figure out why that is on another day. *Note:* When talking about the Clean Air Act in later lessons, you may want to come back to this map to help them remember.

6. **Check for Understanding:** Show students the two portions of the Carbon Brief map below showing the location and size of coal power plants**.**

Area A



Area B

Ask students which area they would expect to have better air quality?

- Air quality will likely be lower in Area A because of the high number and concentration of coal power plants

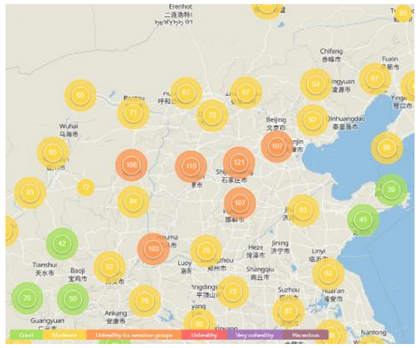
TEACHER NOTES

Teacher Tip

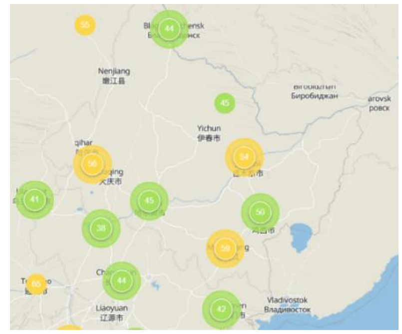
✓ These two areas are both from northern China. If you bring up these maps (or any others) using IQAir, CarbonBrief, and the population density map, you can have students look for patterns in power plants, population, and AQI.

TEACHER NOTES

Actual air quality for these areas (as of June 2020):

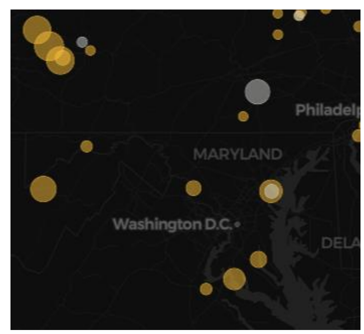


Area A



Area B

7. **Return to the phenomenon.** Remind students that they have been looking at these maps to determine whether the haze in their photos could be man-made. Tell students that the first picture from their phenomenon comes from China (the top right corner of Area A) and the second picture comes from Washington, D.C. Show students the CarbonBrief images of power plants in these two areas. Ask them: based on this information, do they think their hazy day could be cause by air pollution? Hold a short discussion to let students share what they think.



There is some evidence that it could be air pollution, but this is likely not enough. They will need more evidence to be sure.

8. **Formative assessment:** Return to your Investigation Tracker from Activity 1. Based on what you learned today, what important information can you add to your tracker that helps you to understand our hazy day? Key points students could add:
   - The haze could be caused by humans because humans can affect the atmosphere by creating air pollution
   - It could be air pollution from things like coal power plants.
   - There are some power plants near DC, but not a lot
   - There are a lot of people in the DC area

   Afterwards, have students share what they wrote, and encourage them to add good ideas from their peers. You may want to highlight some of these based on the key takeaways above.

Data sources to keep track of

- ✓ Students will use a variety of data sources throughout this module. To help them keep track, you may want to create a poster that lists the data sources and what they're used for. In this activity, they looked at IQAir for AQI data, CarbonBrief for power plant data, and a NASA website for population data.

Differentiation

- ✓ If you are unsure that students will pick up on key points from the lesson before they write in their Investigation Trackers, have a short discussion about big takeaways before the formative assessment instead of after.

Name ______________________________

STUDENT HANDOUT

Pollution, Power Plants, and People

AirIQ Map

What kinds of things do you see on this map?

What do the lower green numbers mean on this map?

What do the higher red and purple numbers mean?

What parts of the world have less air pollution?

What parts of the world have more air pollution?

CarbonBrief Map

What do the big circles on this map represent?

What do the grey/white circles represent?

What do the yellow and pink circles represent?

Where do you see more big power plants opening?

Where do you see more big power plants closing?

World Population

What do the light colors on the map mean?

What do the dark colors on the map mean?

Where are there large populations on the map?

Putting it All Together

What similarities did you notice in terms of where there is pollution, power plants, and people?

Is this pattern the same everywhere in the world?

Why do you think the pattern might be different in some places?

Activity 4 (Explain): The Criteria Air Pollutants

Activity summary: In this activity, students will learn about the 6 Criteria Pollutions defined by the Clean Air Act and the EPA, and they will be introduced to sources of these pollutants. They will use this information to think about what pollutant could be the cause of the haze in their pictures. Then they will learn to look up current and historical AQI data to identify the pollutant that caused the haze in their picture.

Standards Connection
DCI: ESS 3.C – Human Impacts on Earth's Systems
SEP: Obtaining, Evaluating, and Communicating Information

ACTIVITY DETAILS

Time: 45-60 minutes

Objectives

- ✓ Students will define air pollution
- ✓ Students will know there are different kinds of air pollution, and some are more important for us to consider
- ✓ Students will identify the pollutant that caused the Code Red Day in DC

Materials

- ✓ Computer & projector
- ✓ Air pollution information stations (printed & cut)
- ✓ Sources of air pollution signs
- ✓ Scissors (optional for foldable)

Handouts

- ✓ The Criteria Pollutants (foldable or regular) – see note below

Foldable handout (recommended)

- ✓ To use the foldable notes sheet, print it double-sided (**flipped on the short side**). See activity directions for folding.

Warmup: How would you define air pollution?

- After students have answered the warmup question for themselves, have them share ideas while you record on chart paper or on the board. Using their ideas, help them to create a class definition that everyone can agree on. Try not to use the word "pollution" in the definition. Sample definition: "Air pollution is things in the atmosphere that can be harmful to people." Put the definition in a prominent place in the classroom for the rest of the investigation. You may choose to revise it with students at the end of this activity or at any time during the module. The point of this warmup is less to have a perfect definition of air pollution, and more to get students thinking about what air pollution is and what they already know about it.

1. **Frame the Activity:** Remind students that at the end of the last activity, they decided that air pollution *could be* the cause of the haze in their photographs, but they weren't sure. In this activity, they will investigate different kinds of air pollution to see if they can figure out what specific kind of pollution could be causing the haze in their pictures.

2. **Types of Air Pollution.** Hand out the Types of Air Pollution graphic and put it up on the screen. Have students start by looking at the top row. Tell them that these are all different kinds of air pollution. See if students have ever heard of any of them. They may be familiar with ozone, carbon monoxide, or lead. Next have students look at the middle row. They are likely already familiar with the phases of matter. Tell students that air pollution doesn't need to be a gas. Ask them what other liquids they know that might be in the air (water) or what kind of solid (dust). *Note: The goal of this lesson is begin building students' background knowledge on air pollution types, sources, and trends. It is not necessary to go into depth on the types of air pollution at this time.*

TEACHER NOTES

Using the foldable

- ✓ Have students hold the sheet with the solid lines side facing up. Then have them fold the left and right sides into the middle so they meet at the center. You can also have them cut the dotted lines on the front (just to the fold) so they can open the flaps. They can then tape or glue the foldable into their notebooks if they choose. Make sure students know how to use the foldable to take notes.

Modification

- ✓ Take notes on one of the criteria pollutants together as a class before students begin the station work.

Modification

- ✓ Instead of having students rotate from one station to the next, have them pass the materials to the next group.

3. **Identifying the 6 Criteria Pollutants**. Tell students that the United States has a government agency called the Environmental Protection Agency (the EPA) that is responsible for monitoring and preventing pollution. In 1970, a law was passed called the Clean Air Act. That law requires the EPA to monitor 6 particular air pollutants. Ask students why they think these 6 pollutants were chosen (they can be harmful to human health, and they were a big problem when the law was passed in 1970). Tell students that they will learn more about the Clean Air Act later in their investigation.

   See if students can identify the 6 *criteria* pollutants using the graphic: sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), particulate matter (PM), and lead. If students have done Module 1, they will already be familiar with ozone, but the others are probably new to them. They will learn more about ozone in this module, and particulate matter in the Module 3.

4. **Where Does Air Pollution Come From?** Hand out "The Criteria Pollutants" notes sheet (either the foldable or the regular sheet) to students. If you are using the foldable (recommended), have them fold the notes sheet using the directions in the side bar. Tell students that they will be doing some research on the criteria pollutants to learn more about them and see if they can identify which pollutant caused the haze in Washington D.C. on July 9th. For each pollutant, they will write down a few details of what it is, and where it comes from. If they are using the foldable, they also have space to write down clues as to whether they think the pollutant could be the cause of the Code Red Day and why.

   Divide students up into six groups, and give each group copies of the pollutant information for one station. Have them take notes on that pollutant on their notes sheet. After all groups have finished, have them move to the next station to take notes. Repeat until all students have visited each station and taken notes.

5. **Summarizing criteria pollutants and sources:** Have students return to their original seats. Have them review and summarize what they learned together as a class by asking the questions below:
   - What did you notice about the sources of different air pollutants? (they tend to be the same or similar)
   - What are the major sources of most of these air pollutants?
     - Power plants (SO_2, NO_2, O_3, PM)
     - Vehicles (NO_x, CO, O_3, PM)
     - Industrial/Chemical plants (SO_2, O_3, PM, Lead)
     - Natural sources like forest fires (PM, NO_2)

   As students name these sources, put up the corresponding "Sources of Air Pollution" poster on the wall to go with it.

- Based on your research, what pollutant do you think could be causing the haze?
  - At this point, students should be able to identify ozone as the culprit (or possibly PM). It occurs during the summer months, and it looks like a "dirty fog". Other pollutants are the wrong color or colorless (NO_2, SO_2, Lead, CO) or are present in the winter (CO). PM could definitely be a possibility, but because ozone is referred to specifically by color, it is the better choice.

    Don't tell students whether they are right or wrong, but let them know they'll find out the truth in a moment.

6. **Story of a Code Red Day:** Tell students that on June 10, 2018 (the day after the Code Red Day from our picture) there were several news stories written about it. They are going to read a summary of one of those stories to see if they are right about their hypothesis. Hand out the double-entry journal article: *Region's air quality reached unhealthy Code Red levels on Monday.* If necessary, review with students how to complete the double-entry journal, and provide support while they read and answer the questions.

   Afterwards, review students' responses to the questions, and celebrate that they were able to figure out what was going on in the picture.

7. **Return to the investigation tracker:** Have students take out their Investigation Trackers, and add new information to show what they learned about the cause of the haze and the Code Red Day. They should add information about what the pollutant was (ozone) and where ozone comes from. They can get this information from their notes sheet.

8. **Formative assessment:** Go back to your definition of air pollution, and add additional details to include what you've learned today about the criteria pollutants and where they come from.
   - Additional details students might add include the names of the criteria pollutants, the main sources of the criteria pollutants (in general) and why they were chosen as important.

TEACHER NOTES

Differentiation

- ✓ Read the article out loud with students and give them time to answer the questions along the way.

Modification

- ✓ Instead of having students complete this formative assessment, you can use their Investigation Trackers as the formative assessment for this lesson

Types of Air Pollution

Gases				Liquids	Solids		All Phases
Ground-Level Ozone O_3	Sulfur Dioxide SO_2	Nitrogen Dixide NO_2	Carbon Monoxide CO	Particulate Matter PM_{10} & $PM_{2.5}$	Particulate Matter PM_{10} & $PM_{2.5}$	Lead	Toxic Chemicals
Criteria Pollutants							Air Toxics

Station 1: Particulate Matter (PM)

What is it?
Particulate matter (PM) is very, very small particles of pollution like dust, pollen, soot, and other chemicals. Particulate matter can be a solid or a liquid that floats in the air.

Where does it come from?
Particulate matter comes from a variety of sources, such as factories, power plants, and vehicles like cars and trucks. It can also come from natural sources, such as forest fires and volcanoes. These particles may be emitted directly into the air, or they may be formed by chemical reactions in the atmosphere. Particle pollution can occur year-round.

Station 2: Ground-level Ozone (O_3)

What is it?
Ground level ozone is the main ingredient in urban and regional smog. Smog looks like a dirty fog that can blanket urban areas. Unhealthy levels of ground level ozone occur during the summer months, typically May through September.

Where does it come from?
Ozone does not come directly from pollution sources. Instead, pollution like Nitrogen Oxides (NOx) and other chemicals are released from cars, paint, gas-powered lawnmowers, boats, power plants, and industrial facilities. These pollutants react with heat and sunlight, which makes ground level ozone.

Station 3: Carbon Monoxide (CO)

What is it?
Carbon monoxide (CO) is a colorless, odorless gas that is produced by incomplete burning of fossil fuels like gasoline, natural gas, coal, oil, etc.

Where does it come from?
Over half of the CO emissions in the country come from motor vehicle exhaust. Other sources include construction equipment, boats, lawnmowers, woodstoves, forest fires, and industrial manufacturing processes. Carbon monoxide levels tend to be higher in the colder months.

Station 4: Sulfur Dioxide (SO_2)

What is it?
Sulfur Dioxide (SO_2) is a colorless gas that has a strong odor. SO_2 can dissolve in water vapor to produce acid rain.

Where does it come from?
Sulfur Dioxide comes from burning of fuels containing sulfur (such as coal and oil), petroleum refining, and smelting (extracting metals from ore), and it also occurs naturally from volcanic eruptions.

Station 5: Lead

What is it?
Lead is a metal found naturally in the environment as well as in manufactured products. When it is very fine, lead can be an air pollutant even though it is a solid. Lead particles in the air are usually too small to be seen.

Where does it come from?
Today, the major sources of lead pollution are smelters that purify lead from rocks (ore), waste incinerators, utilities, and lead-acid battery manufacturers. Lead used to be found in gasoline, which caused there to be high levels of lead pollution from cars and trucks that used leaded fuel. Now that leaded gasoline has been banned, lead levels have gone down dramatically.

Station 6: Nitrogen Dioxide (NO_2)

What is it?
Nitrogen dioxide (NO2) is a gas that has a reddish-brown color and pungent odor. It can dissolve in water vapor to form acid rain, and it can also react with other chemicals to make ground-level ozone.

Where does it come from?
Nitrogen dioxide comes from high-temperature burning of fossil fuels in automobiles, power plants, and other industrial, commercial, and residential sources. It can also occur naturally from lightning, forest fires, and bacteria in the soil.

Name ______________________________

STUDENT HANDOUT

The Criteria Pollutants

Station 1: Particulate Matter **What is it?** **Sources:**	**Station 2: Ozone (O_3)** **What is it?** **Sources:**
Station 3: Carbon Monoxide (CO) **What is it?** **Sources:**	**Station 4: Sulfur Dioxide (SO_2)** **What is it?** **Sources:**
Station 5: Lead **What is it?** **Sources:**	**Station 6: Nitrogen Dioxide (NO_2)** **What is it?** **Sources:**

Particulate Matter (PM)

Sources

Could it cause the haze?

Why or why not?

Ozone (O_3)

Sources

Could it cause the haze?

Why or why not?

Carbon Monoxide (CO)

Sources

Could it cause the haze?

Why or why not?

Sulfur Dioxide (SO_2)

Sources

Could it cause the haze?

Why or why not?

Lead

Sources

Could it cause the haze?

Why or why not?

Nitrogen Dioxide (NO_2)

Sources

Could it cause the haze?

Why or why not?

Station 2

Ozone

What is it?

Station 1

Particulate Matter

What is it?

Station 4

Sulfur Dioxide

What is it?

Station 3

Carbon Monoxide

What is it?

Station 6

Nitrogen Dioxide

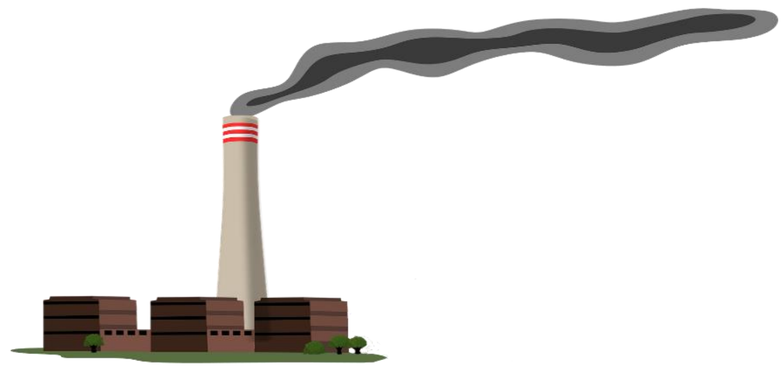
What is it?

Station 5

Lead

What is it?

Power Plant



Air Pollutants

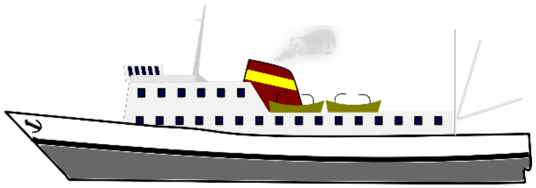
Sulfur Dioxide (SO_2)

Nitrogen Dioxide (NO_2)

Ground-Level Ozone (O_3)

Particulate Matter (PM)

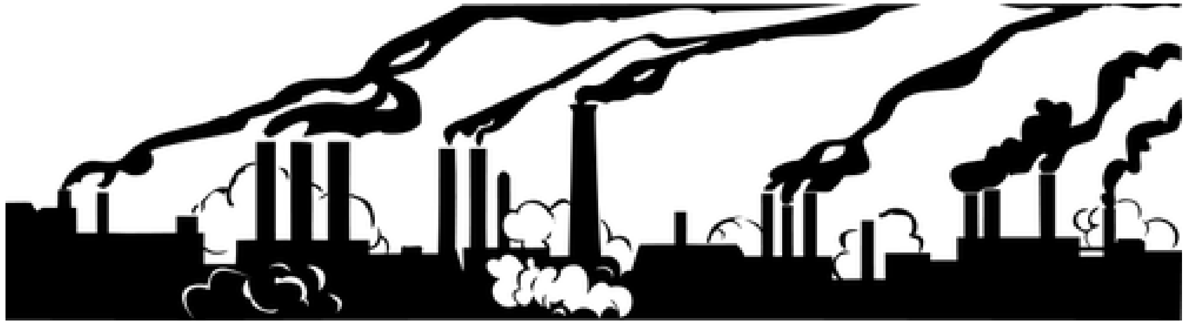




Transportation

Air Pollutants

Nitrogen Dioxide (NO_2)
Carbon Monoxide (CO)
Ground-Level Ozone (O_3)
Particulate Matter (PM)



Manufacturing

Air Pollutants

Sulfur Dioxide (SO_2)
Ground-Level Ozone (O_3)
Particulate Matter (PM)
Lead

Natural Sources

<u>Air Pollutants</u>

Particulate Matter

Nitrogen Dioxide

Name ______________________________

Region's air quality reached unhealthy Code Red levels on Monday

Jul 10, 2018
Washington, D.C. (July 10, 2018)

Ground-level ozone reached unhealthy air quality levels yesterday in metropolitan Washington, marking the first "Code Red" air day for the region this year—and the first since 2012.	**How many Code Red Days were there in the Washington, D.C. region between 2013 and 2017?**
Today is forecast to be a "Code Orange" day, unhealthy for sensitive groups, according to data from the Metropolitan Washington Council of Governments (COG) and Clean Air Partners. Code Orange days are one step safer than Code Red days.	**Was the air quality on July 10, 2018 better or worse than the day before?**
Monday had sunny skies and low wind, which can lead to bad air pollution. The high temperature was 88° F. When the air is stagnant, pollution can become more concentrated than when the air is moving quickly.	**What is the meaning of the word "stagnant" in this paragraph?**
During times of Code Red unhealthy air, all people should limit their outdoor activity. Sensitive groups like children, older adults, and people with respiratory and heart ailments may experience more serious health effects. Residents can check current air quality conditions at www.mwcog.org.	**What kinds of people are considered "sensitive" to air pollution?**

Exposure to air pollution can have many different health effects on people. Air pollution can irritate lungs, and may trigger asthma attacks. Long-term exposure to air pollution can also increase your risk of a heart attack or lung cancer.	**Why is air pollution harmful?**
According to the U.S. Environmental Protection Agency (EPA), "emissions from industrial facilities and electric utilities, motor vehicle exhaust, gasoline vapors, and chemical solvents are some of the major sources" of the pollution that is causing the Code Red day.	**Name three major sources of air pollution:**
On unhealthy air days, COG advises area residents to take the following actions: • Download the free air quality app at www.cleanairpartners.net for current air quality information. • Turn off lights and electronics when not in use and follow tips from your electric utility about how to use less electricity to cool your home. • Avoid lawn mowing or use an electric mower. • Fill your vehicles' gas tank after sunset. • Take transit, carpool, or work from home.	**Name three things you can turn off to help with air quality:**

Adapted from: *Region's air quality reached unhealthy Code Red levels on Monday*, Metropolitan Washington Council of Governments, https://www.mwcog.org/newsroom/2018/07/10/regions-air-quality-reached-unhealthy-code-red-levels-on-monday/

Name ______________________________

TEACHER'S GUIDE

Region's air quality reached unhealthy Code Red levels on Monday

Jul 10, 2018
Washington, D.C. (July 10, 2018)

Ground-level ozone reached unhealthy air quality levels yesterday in metropolitan Washington, marking the first "Code Red" air day for the region this year—and the first since 2012.	**How many Code Red Days were there in the Washington, D.C. region between 2013 and 2017?** **There were zero Code Red days in the D.C. area between 2013 and 2017**
Today is forecast to be a "Code Orange" day, unhealthy for sensitive groups, according to data from the Metropolitan Washington Council of Governments (COG) and Clean Air Partners. Code Orange days are one step safer than Code Red days.	**Was the air quality on July 10, 2018 better or worse than the day before?** **The air quality was better.**
Monday had sunny skies and low wind, which can lead to bad air pollution. The high temperature was 88° F. When the air is stagnant, pollution can become more concentrated than when the air is moving quickly.	**What is the meaning of the word "stagnant" in this paragraph?** **Not moving or still**
During times of Code Red unhealthy air, all people should limit their outdoor activity. Sensitive groups like children, older adults, and people with respiratory and heart ailments may experience more serious health effects. Residents can check current air quality conditions at www.mwcog.org.	**What kinds of people are considered "sensitive" to air pollution?** **Children, older adults, and people with respiratory or heart problems**

Exposure to air pollution can have many different health effects on people. Air pollution can irritate lungs, and may trigger asthma attacks. Long-term exposure to air pollution can also increase your risk of a heart attack or lung cancer.	**Why is air pollution harmful?** **Air pollution can cause many different health problems like asthma attacks, heart disease, and lung cancer.**
According to the U.S. Environmental Protection Agency (EPA), "emissions from industrial facilities and electric utilities, motor vehicle exhaust, gasoline vapors, and chemical solvents are some of the major sources" of the pollution that is causing the Code Red day.	**Name three major sources of air pollution:** **Many possible answers including:** **Cars, trucks, power plants (electric utilities), chemical plants, gasoline, and factories (industrial facilities)**
On unhealthy air days, COG advises area residents to take the following actions: • Download the free air quality app at www.cleanairpartners.net for current air quality information. • Turn off lights and electronics when not in use and follow tips from your electric utility about how to use less electricity to cool your home. • Avoid lawn mowing or use an electric mower. • Fill your vehicles' gas tank after sunset. • Take transit, carpool, or work from home.	**Name three things you can turn off to help with air quality:** **Many possible answers including:** **Computer, television, lights, video games, phone, etc.**

Adapted from: *Region's air quality reached unhealthy Code Red levels on Monday*, Metropolitan Washington Council of Governments, https://www.mwcog.org/newsroom/2018/07/10/regions-air-quality-reached-unhealthy-code-red-levels-on-monday/

Activity 5 (Explain): O_3, Oh My! Getting to Know Ozone

ACTIVITY DETAILS

Time: 30 minutes

Objectives
- ✓ Students will understand what ozone is from both a general and chemical perspective
- ✓ Students will understand the different between beneficial (stratospheric) and harmful (tropospheric) ozone

Materials
- ✓ Computer & projector
- ✓ Speakers
- ✓ Student computers (optional)

Handouts
- ✓ Ozone: Good up High, Bad Nearby Venn diagram

Differentiation
- ✓ For advanced students: Give students a blank Venn diagram, have them take their own notes from the video, and then organize them using the diagram

Activity summary: This shorter activity begins an opportunity for students to share what they know or have heard about ozone. After this, they watch a video and interpret an infographic to build their background knowledge about ozone. Students organize their understanding using a Venn diagram about different forms of ozone.

Standards Connection

DCI: ESS 3.C – Human Impacts on Earth's Systems
DCI: ESS2.D – Weather & Climate
SEP: Obtaining, Evaluating, and Communicating Information

Warmup: Primary air pollutants are pollutants that are released directly into the air from pollution sources. Ozone is not a primary pollutant, it is a secondary pollutant. Based on what you learned yesterday, why do you think ozone is called a secondary pollutant?

- Ozone is a secondary pollutant because it is formed from a chemical reaction between different primary pollutants
- The purpose of this warmup is to reinforce the idea that ozone is not emitted directly. This can be confusing for students, so it is worth emphasizing.

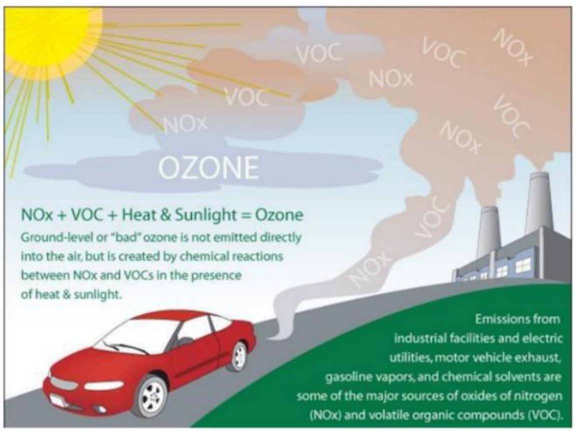
1. **Frame the activity:** Tell students that now that they know that ground-level ozone was the cause of the haze in Washington on the Code Red day, we need to learn more about it as a pollutant. By learning where it comes from, we can work on ways to predict and prevent bad ozone days in the future. Today they're going to study ozone in more depth to see what they can uncover.

2. **What Do You Think?** Prepare a piece of chart paper (or a place on the board) to record student responses for this part of the activity. Then ask students what they know about ozone. Some may have heard about it, and it may be new to others. Record each answer on the board where all students can see. If students get stuck, prompt them with questions such as: "Is ozone good or bad?", or "Where does ozone come from?" Don't tell students which statements are accurate or inaccurate, just focus on letting them share. When students are finished sharing, tell them that you will come back to this list later as a class to see what they've learned.

   The purpose of this part of the activity is to activate students' background knowledge, and to see what students know about ozone. Students may have heard of the ozone layer before, and it is important to begin helping them to differentiate between ground-level ozone and stratospheric ozone.

2. **Ozone: Good Up High, Bad Nearby.** Hand out the ozone Venn diagram "Ozone: Good Up High, Bad Nearby" for students to take notes during the ozone video, and give students some time to consider what information they are looking for. Show them the video *Ground Level Ozone: What is It?* (or have them watch it using student computers): www.youtube.com/watch?v=THY0UULn_2U. You may want to show it twice so students can fill in additional information on their graphic organizers. After they have finished, review the information on the graphic organizer to clear up any student misconceptions.

3. **Connecting Ozone to Emissions**. Show students the graphic below from the US EPA:



Source: US EPA

Use the graphic to help strengthen the fact for students that ozone does not come directly from pollution sources like factories and power plants. Instead, the chemicals that come from these sources react using sunlight and heat to make ozone. Add any additional information to the Venn diagram that is helpful.

4. **I used to think, but now I think.** Return to the "What Do You Think?" activity from the beginning of the lesson. Go through each of the statements you wrote down, and have students decide if it is true, partially true, or not true. If it is only partially true, have students turn to a partner and fix the statement by saying, "I used to think… <then the statement> but now I think… <what they've learned now>". For example:
   - I used to think that ozone was bad for you, but now I think that only some ozone is bad for you and some is good for you.
   - I used to think that ozone was a layer high in the sky, but now I think that ozone can also be low to the ground.

   Students can also add new statements if they want to show what they've learned during this activity.

TEACHER NOTES

Teacher Tip

✓ Use the "I used to think… " part of the activity to prepare students to complete the formative assessment on the next page.

TEACHER NOTES

Teacher Tip

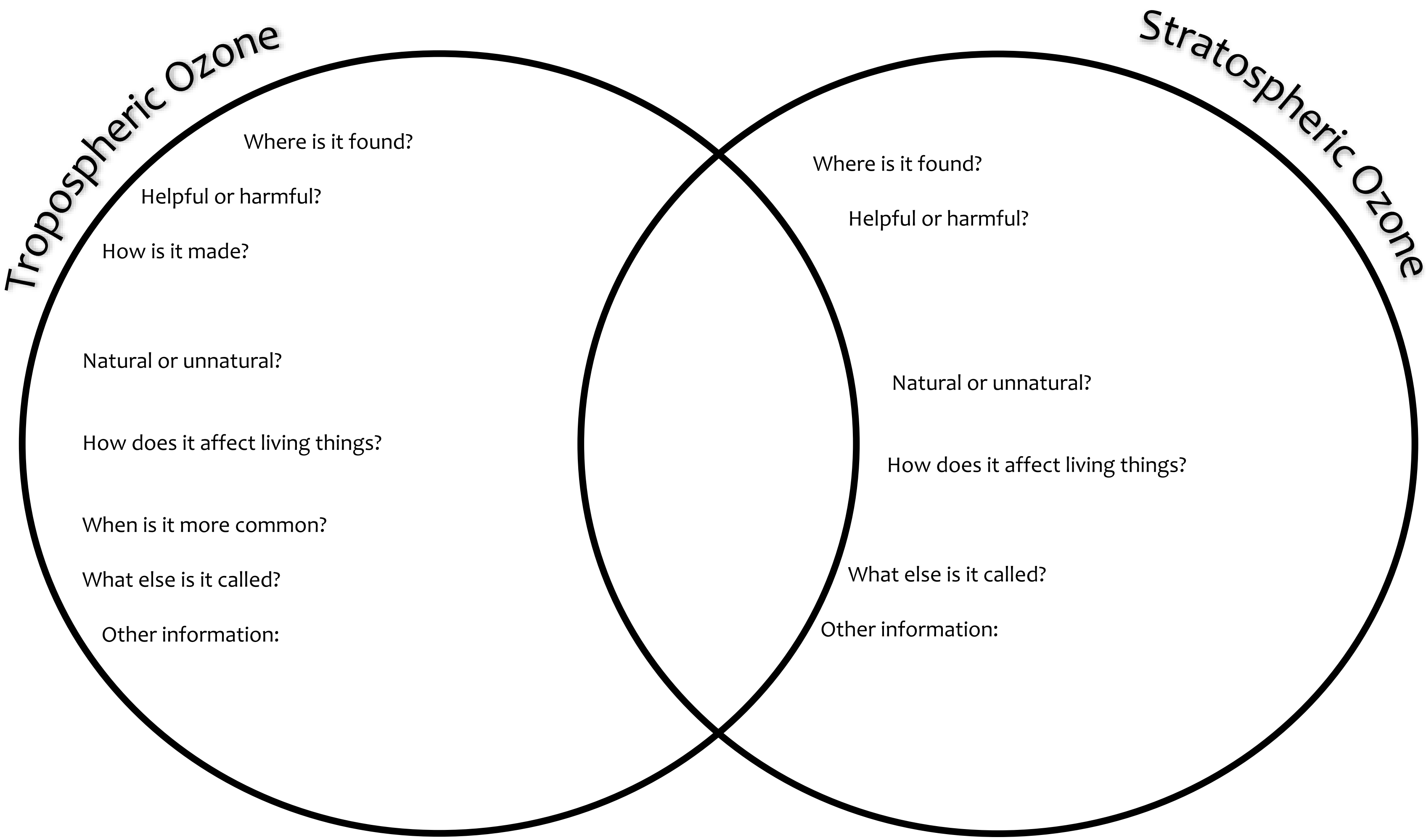
✓ Checking students' completed Venn diagrams is another way to assess their understanding of ozone.

Formative assessment: return to the investigation tracker: Have students return to their Investigation Trackers to add what they've learned about ozone. Key ideas:

- There are two kinds of ozone: ground-level ozone and stratospheric ozone
- Ground-level ozone (tropospheric) is a harmful pollutant that can hurt people's lungs and damage crops
- Stratospheric ozone (in the ozone layer) protects Earth from harmful radiation
- Ground-level ozone is formed when certain kinds of air pollution react with heat and sunlight
- You can prevent ozone from forming by using less electricity and driving less

Name________________________________

Ozone: Good Up High, Bad Nearby



TEACHER GUIDE

Ozone: Good Up High, Bad Nearby

Tropospheric Ozone

Where is it found? **Near the ground**

Helpful or harmful? **Harmful**

How is it made? **When air pollutants react together with heat and sunlight**

Natural or unnatural? **Unnatural**

How does it affect living things? **It hurts your lungs and it can damage crops**

When is it more common? **In the summer**

What else is it called? **Smog**

Other information: **You can prevent ozone from forming by driving less, using less gas-powered tools, and using less electricity**

Ozone

Formula: **O_3**

Element: **Oxygen**

Other information:

Stratospheric Ozone

Where is it found? **High in the atmosphere**

Helpful or harmful? **Helpful**

Natural or unnatural? **Natural**

How does it affect living things? **Protects living things from harmful UV radiation**

What else is it called? **The ozone layer**

Other information:

Activity 6 (Explore): Air Quality in the DC/Baltimore Region

Activity summary: In this activity, students learn about what the Air Quality Index (AQI) is to better understand what a Code Red Day is. They use the Clean Air Partners website to research the history of air quality in the region to see patterns in how it has changed over time.

Standards Connection
DCI: ESS 3.C – Human Impacts on Earth's Systems
SEP: Obtaining, Evaluating, and Communicating Information
CCC: Patterns

Warmup: Look at the definition we created for air pollution earlier in this investigation. Based upon what we have learned so far, how would you define the term "air quality"?

- After students have completed the warmup, have them share with a small group to come up with a common definition. Then have groups share out, and develop a common class definition of air quality. Put this definition up on the wall with the definition for air pollution, and revisit it as necessary in the module to add detail.
- Sample definition: "How clean the air is based on how little air pollution there is"

1. **Frame the Activity:** Tell students that they now have a good understanding of what happened in Washington, D.C. on July 9, 2018. That day was called a Code Red Day. Ask students why they think it might have been called "Code Red"? They will likely say something like – because it is dangerous, and red is a color that means danger. Acknowledge their suggestions, but don't tell them if they are right or not. Ask them if they think there have been other Code Red Days in the area. After they have a chance to respond, tell them that today they are going to learn about why that day was called a Code Red day, and they'll learn about how air pollution in the area has changed over time.

2. **The Air Quality Index (AQI).** Tell students that they are going to start by reading an article that explains what a Code Red Day is. Pass out the double-entry journal article "The Air Quality Index". Review the directions, then have students read and complete the questions. Afterwards, review the answers to check for student understanding. In particular, make sure students understand why the day was called a Code Red Day.

ACTIVITY DETAILS

Time: 2 class periods

Objectives

- ✓ Students will learn to interpret the Air Quality Index (AQI)
- ✓ Students will research current and historical AQI data from the DC/ Baltimore area
- ✓ Students will identify the major air pollutants in the DC/Baltimore area and analyze data to show how they have changed over time

Materials

- ✓ Computer & projector
- ✓ Students computers (highly recommended)
- ✓ "The air quality today in <blank> is…" (see activity)

Handouts

- ✓ Air Quality Index reading (double-entry journal)
- ✓ Historical AQI Data Investigation
- ✓ AQI Through the Years
- ✓ Graph paper (optional)

TEACHER NOTES

Connection to Module 1

- ✓ If you have done Module 1 with students, you may want to skip over the AQI portion of the activity, or use this time to review what students have already learned about the AQI.

The Air Quality Today in <blank> is…

- ✓ To give students practice looking up the AQI, create a series of signs that say "The air quality today in <blank> is… <blank> due to <blank>" that students can change the numbers on (ex. with a taped-on notecard or using a dry erase board). Make one sign for the location of the school. Also have students choose cities they want to look up the AQI for each day (preferable cities around the world). Start each day by having students update the numbers on the sign and compare what it would be like to be a middle school student in different cities on that day.

Show students a color version of the scale (either printed out or projected) to review the different colors and what they mean, including the numbers and what you should do if the level of pollution on the index is reached.

3. **Looking up the current AQI:** Tell students that there are a lot of different ways to find out what the current air quality is in their neighborhood or around the world. Pass out student computers (if available) or project a web browser were all students can see. With students, go to the Clean Air Partners website for current and forecasted AQI: https://www.cleanairpartners.net/current-and-forecasted-air-quality. Click on "current" at the top right corner of the map to see the AQI color in different places in the area. Click on the point on the map closest to where the school is. The page will scroll to the bottom where there is specific AQI data. You can also switch pollutants to see how the AQI changes.

   If you have not already, put up the "The air quality today in <blank> is… " signs somewhere in the classroom. Choose a student to write in the AQI for the school location, including what the AQI is due to (ozone, PM, etc.). Next, have students go to the World Air Quality Index website: http://www.waqi.info/. Students can use the map to find and click on another city to look up its AQI, or they scroll down and type a city into the search bar. As a class, choose a few more cities to look up the AQI for. Put these city names into your other signs, and have students put in the AQI information including what it is due to. Try to pick cities that are in different parts of the world and that have different AQIs. Every day at the beginning of class, have students look up the AQI in those cities to update the signs.

   Before moving on, share other ways that students can look up the AQI, for example using apps on their phones such as Clean Air Partners Air Quality app, and the Air Visual app. If students are allowed to use their smartphones at school, show them how they can add these apps to their phones to look up the AQI.

4. **Researching Historical AQI Data.** Remind students of when you asked them earlier about whether there have been other Code Red Days in the area besides July 9, 2018. Tell them that in this next part of the activity, they are going to find out. Pass out the AQI Data Investigation sheet, and tell students that they are going to research Code Red days from the past to look for patterns in how air pollution in the area has changed over time.

Read the directions at the top of the sheet with students to bring them back to the Clean Air Partners website where they can look at looking at the historical air quality data: https://www.cleanairpartners.net/historical-air-quality

Start by having all students look up the same date: July 20, 2017 is a good choice since it was a Code Red Day. Once students have navigated to the information, have them answer the questions on their handouts.

- What was the AQI for this date? **151**
- What was the Particulate Matter (PM) AQI? **71**
- Where was the PM AQI the highest (what site name)? **Millington**
- What was the Ozone AQI? **151**
- Where was the Ozone AQI the highest? **Edgewood**
- Why was this a Code Red day in the area? **Ozone over 150**

After this example, have students go to 3 other dates that each have a different AQI color (green, yellow, and orange), and have them answer the questions on their handout for those dates. Note that going back in time will likely lead to worse pollution days, and the summer has worse pollution than other seasons. July 2017 has four different levels, so students can also stay on that month.

Once students are finished with the historical research, they can answer the questions at the bottom of the sheet. Review the answers when all students are finished:

- Most poor air quality days in the DC/Baltimore region are caused by particulate Matter (PM 2.5) and Ozone (in fact, many sensors in the area only measure these two pollutants)
- The pollutant which caused the Code Red Day on July 9, 2018 was ozone with an AQI of 166 in Beltsville, MD

Once students have finished with this part of the activity, you can collect their computers.

Timing Note: If you are doing this activity over the course of two (or more) days, this is a good point to break up the activity.

TEACHER NOTES

Technology Tip

- ✓ The Clean Air Partners historical data website can be slow at times. Be patient and the data will come up. With this said, be sure to have a back-up plan (ex. download the data in advance and be ready to display it for students).

Modifications

- ✓ If student computers are not available for this activity, you can either look up the information together as a class using a projector, or print out copies of the calendars for students to look at. In this case, have them color in the different days based upon their AQI level (the number is listed on each calendar day)

TEACHER NOTES

Teacher Tip

- ✓ If students are working off of a black & white copy of the handout, it will be hard to count the number of days of each AQI (they can see the numbers, but they are small). It will help if you project a copy of the handout so students can more easily count the colors

Digging Deeper

- ✓ There was only one Code Red day in July, 2020. Did you notice what day it was? The AQI was in the yellow or green for almost all locations except for two, where it was in the red for PM. What could have added PM to the air on this date?

Data Analysis

- ✓ The "Analysis" answers here are very vague since the answers will be different depending the analysis method you choose to use with students. These answers provide the minimum information needed to draw conclusions.

5. **AQI Through the Years.** Ask students if they think the air quality in the area has been getting better or worse since you were a kid. Listen for student responses (students generally think that it has gotten worse), then tell them that they are going to be looking at data to see if their predictions are right or not. Pass out the sheet "AQI Through the Years." Have students read the top part of the sheet, and then review with them what information is shown (it is the July AQI calendars every 5 years 1995-2020). Have students count and graph (optional) the number of days for each AQI level (color).

Year	Green	Yellow	Orange	Red	Purple
1995	0	7	7	11	6
2000	8	11	8	4	0
2005	1	16	6	6	2
2010	2	14	7	8	0
2015	1	29	1	0	0
2020	8	20	2	1	0

Once they are finished counting/graphing, discuss with students how they can analyze patterns in these data (see note below for ideas). When you have decided on an option (or options) have students complete the analysis and answer the questions on the back of their sheet.

A Note about Data Analysis & Math Integration

There are many ways to analyze these data. The most complex analysis would be to make a scatter plot for each color, then draw a line of best fit and determine the slope to see how the number of days of each color is changing over time. Depending on students' grade level and current math ability this may be too advanced. You can also have students average the first three years for each color and the last three years and compare the averages to see how the number of days is changing in general. You can have students find the average of all the numbers for a particular color and then compare the numbers in 1995 and 2020 to the average. The point is, use whatever math skills your students have (or are working on) to look for a pattern in the way the numbers are changing.

Analysis: How have the number of each of the days changed?

- Green: stayed about the same
- Yellow: went up a lot
- Orange: went down a little
- Red: went down
- Purple: went down

When students are finished with their analysis, discuss what *trends* they see in the data. In other words, patterns of change are not always smooth (linear), but they may still go in one direction or another. For example, 2000 was a pretty good July for air quality, but it is more likely the exception than the rule. Make sure that students understand that overall, the air quality is getting better, but there can still be good or bad years for various reasons.

6. **Reaching a conclusion:** After the discussion, have students answer the conclusion question using data from this activity.

   Sample response: The amount of air pollution in the DC area in July has gone down since 1995. In 1995, there were 6 days in the purple range (very unhealthy), but there were 0 purple days in 2010, 2015, and 2020. The number of red days (unhealthy) has gone down as well. The number of yellow days (moderately unhealthy) has gone up, but this is because there are less red and purple days.

7. **Return to the Investigation Tracker:** Have students make notes in their investigation tracker based on big ideas they learned during this activity. Key takeaways:
   - Air quality is measured using a scale call the Air Quality Index (AQI)
   - The main air pollutants in the DC-Baltimore area are particulate matter (PM) and ozone.
   - Air quality in the DC-Baltimore area is improving

8. **Formative Assessment.** Show students this calendar and tell them that this is the July AQI data from the DC area for some time between 1995 and 2020. Based upon what they learned today, what year would they predict this data is from? How did they choose that year? How confident are they in their prediction?

Sun	Mon	Tue	Wed	Thu	Fri	Sat
						01 AQI:105 details
02 AQI:150 details	03 AQI:150 details	04 AQI:147 details	05 AQI:61 details	06 AQI:44 details	07 AQI:46 details	08 AQI:77 details
09 AQI:93 details	10 AQI:122 details	11 AQI:161 details	12 AQI:136 details	13 AQI:48 details	14 AQI:105 details	15 AQI:54 details
16 AQI:61 details	17 AQI:212 details	18 AQI:221 details	19 AQI:187 details	20 AQI:136 details	21 AQI:147 details	22 AQI:54 details
23 AQI:51 details	24 AQI:122 details	25 AQI:90 details	26 AQI:97 details	27 AQI:136 details	28 AQI:46 details	29 AQI:129 details
30 AQI:87 details	31 AQI:154 details					

   - The actual month is **July, 2006.**
   - Students should be able to predict that this is likely in the 2005-2010 range (though they may also go as far as 2015) because it has 5 red/purple days (similar to 2005 & 2010) and 22 yellow/orange days (similar to 2015 & 2010)
   - They should also be fairly uncertain about the year, partly because they don't know what year it is in the range, and partly because they know that conditions can vary from year to year.

TEACHER NOTES

Research sources

✓ If you are using chart paper to make of list of research sources for the module, you can add the Clean Air Partners website and the World Air Quality Index website as sources of AQI data.

Homework suggestion

✓ Have students show their parents or guardians how to find the AQI at home (using a computer or phone) and explain what it means.

Name ______________________________

STUDENT READING

The Air Quality Index

What is the AQI? The Air Quality Index or "AQI" is a tool used to report daily air quality. The AQI uses color-codes and a numerical scale to report how clean or polluted the air is and what associated health effects might be of concern. The AQI focuses on health effects people may experience within a few hours or days after breathing polluted air. A different AQI is calculated for each of the major pollutants regulated by the Clean Air Act except for lead: particulate matter, ozone, carbon monoxide, sulfur dioxide, and nitrogen dioxide. The overall AQI for a day is equal to the worst AQI score for any of the 5 pollutants. For example, if the AQI for ozone is 52, and the AQI for PM is 86, then the overall AQI for the day is 86.	**What are the two ways that the AQI reports air quality information?** **How long might a person feel the effects of breathing polluted air?** **What are the pollutants that are included in the AQI?**
How Does the AQI Work? Think of the AQI as a yardstick that runs from 0 to 300. The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 represents good air quality with little potential to affect public health, while an AQI value over 200 represents very unhealthy air quality. An AQI value of 100 generally corresponds to the national air quality standard for the pollutant, which is the level the Environmental Protection Agency (EPA) has set to protect public health.	**What AQI value matches with the EPA limit for a pollutant?**

Air Quality Index Levels of Health Concern	Numerical Value	Meaning
Good	0-50	Air quality is considered good, and air pollution poses little or no risk.
Moderate	51-100	Air quality may pose a moderate health risk, especially for those who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	101-150	Members of sensitive groups, children and adults with respiratory and heart ailments, may experience health effects and should limit time spent outside. The general public is not likely to be affected.
Unhealthy	151-200	Everyone may experience health effects and should limit their outdoor activity; members of sensitive groups may experience more serious health effects.
Very Unhealthy	201-300	Everyone may experience more serious health effects and should avoid outdoor activities, especially individuals with heart and breathing ailments, children, and older adults.

The Air Quality Index

AQI values below 100 are generally thought of as satisfactory. When AQI values are above 100, air quality is considered to be unhealthy – at first for certain sensitive groups of people, then for everyone as AQI values get higher.	**What is the range of air quality that is unhealthy for everyone?** **What do you think the level of Air Quality was on the Code Red day we read about?**
Air quality can impact your day as much as the weather and traffic can — which makes checking daily air quality forecasts an equally important part of your routine. Visit the Clean Air Partners Current Air Quality webpage or download the Clean Air Partners Air Quality App to have air quality information at your fingertips.	**How can you find information about the current AQI where you live?**

Source: Adapted from *Air Quality Index* (Clean Air Partners) https://www.cleanairpartners.net/aqi

Name ________________________________

TEACHER GUIDE

The Air Quality Index

What is the AQI?	What are the two ways that the AQI reports air quality information?
The Air Quality Index or "AQI" is a tool used to report daily air quality. The AQI uses color-codes and a numerical scale to report how clean or polluted the air is and what associated health effects might be of concern. The AQI focuses on health effects people may experience within a few hours or days after breathing polluted air. A different AQI is calculated for each of the five major pollutants regulated by the Clean Air Act: particulate matter, ozone, carbon monoxide, sulfur dioxide, and nitrogen dioxide. The overall AQI for a day is equal to the worst AQI score for any of the 5 pollutants. For example, if the AQI for ozone is 52, and the AQI for PM is 86, then the overall AQI for the day is 86.	**As a color-code and a number.** **How long might a person feel the effects of breathing polluted air?** **For hours or days** **What are the pollutants that are included in the AQI?** **PM, ozone, carbon monoxide, sulfur dioxide, and nitrogen dioxide.**
How Does the AQI Work? Think of the AQI as a yardstick that runs from 0 to 300. The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 represents good air quality with little potential to affect public health, while an AQI value over 200 represents very unhealthy air quality. An AQI value of 100 generally corresponds to the national air quality standard for the pollutant, which is the level the Environmental Protection Agency (EPA) has set to protect public health.	**What AQI value matches with the EPA limit for a pollutant?** **100**

STUDENT HANDOUT

Air Quality Index Levels of Health Concern	Numerical Value	Meaning
Good	0-50	Air quality is considered good, and air pollution poses little or no risk.
Moderate	51-100	Air quality may pose a moderate health risk, especially for those who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	101-150	Members of sensitive groups, children and adults with respiratory and heart ailments, may experience health effects and should limit time spent outside. The general public is not likely to be affected.
Unhealthy	151-200	Everyone may experience health effects and should limit their outdoor activity; members of sensitive groups may experience more serious health effects.
Very Unhealthy	201-300	Everyone may experience more serious health effects and should avoid outdoor activities, especially individuals with heart and breathing ailments, children, and older adults.

The Air Quality Index

AQI values below 100 are generally thought of as satisfactory. When AQI values are above 100, air quality is considered to be unhealthy – at first for certain sensitive groups of people, then for everyone as AQI values get higher.	**What is the range of air quality that is unhealthy for everyone?** **151-300** **What do you think level of Air Quality was on the Code Red day we read about?** **Red, unhealthy, 151-200**
Air quality can impact your day as much as the weather and traffic can — which makes checking daily air quality forecasts an equally important part of your routine. Visit the Clean Air Partners Current Air Quality webpage or download the Clean Air Partners Air Quality App to have air quality information at your fingertips.	**How can you find information about the current AQI where you live?** **From websites (like the Clean Air Partners website) or using an app on your phone.**

Source: Adapted from *Air Quality Index* (Clean Air Partners) https://www.cleanairpartners.net/aqi

Name ________________________________

Historical AQI Data Investigation

Directions

1. Open a web browser and go to the Clean Air Partners website for historical air quality data: https://www.cleanairpartners.net/historical-air-quality
2. Use the date dropdown menus to choose the date you are looking for
3. Click on the date "details" to see a summary of the data for that date

Date #1: July 20, 2017
What was the AQI for this date? What was the Particulate Matter (PM) AQI? Where was the PM AQI the highest (what site name)? What was the Ozone AQI? Where was the Ozone AQI the highest? Why was this a Code Red day in the area?

Date #2:
What was the AQI on this date? (color & number): What pollutant had the highest AQI? What was the AQI for this pollutant? What recommendations would you make for people if you were an air quality expert on this day?
Date #3:

What was the AQI on this date? (color & number):

What pollutant had the highest AQI?

What was the AQI for this pollutant?

What recommendations would you make for people if you were an air quality expert on this day?

Date #4:

What was the AQI on this date? (color & number):

What pollutant had the highest AQI?

What was the AQI for this pollutant?

What recommendations would you make for people if you were an air quality expert on this day?

What pollutant or pollutants cause(s) the most bad air quality days in our area? ______________

____

____

What was the cause of the Code Red Day from our article? (July 9, 2018) ____________________

What was the AQI for that pollutant on July 9, 2018? ______________________________

Name ______________________________

STUDENT HANDOUT

AQI Through the Years

Look at the calendars below that show the AQI for the month of July every five years starting in 1995:

Historical Data

Year: 1995 Site: All Sites View
Month: July Pollutant: Maximum AQI

Sun	Mon	Tue	Wed	Thu	Fri	Sat
						01 AQI:87 details
02 AQI:84 details	03 AQI:90 details	04 AQI:126 details	05 AQI:87 details	06 AQI:105 details	07 AQI:84 details	08 AQI:136 details
09 AQI:80 details	10 AQI:140 details	11 AQI:190 details	12 AQI:208 details	13 AQI:205 details	14 AQI:219 details	15 AQI:228 details
16 AQI:143 details	17 AQI:197 details	18 AQI:151 details	19 AQI:161 details	20 AQI:182 details	21 AQI:192 details	22 AQI:203 details
23 AQI:126 details	24 AQI:161 details	25 AQI:161 details	26 AQI:154 details	27 AQI:151 details	28 AQI:93 details	29 AQI:147 details
30 AQI:187 details	31 AQI:216 details					

Historical Data

Year: 2000 Site: All Sites View
Month: July Pollutant: Maximum AQI

Sun	Mon	Tue	Wed	Thu	Fri	Sat
						01 AQI:140 details
02 AQI:156 details	03 AQI:151 details	04 AQI:126 details	05 AQI:100 details	06 AQI:100 details	07 AQI:45 details	08 AQI:58 details
09 AQI:174 details	10 AQI:126 details	11 AQI:50 details	12 AQI:74 details	13 AQI:74 details	14 AQI:119 details	15 AQI:74 details
16 AQI:67 details	17 AQI:122 details	18 AQI:126 details	19 AQI:34 details	20 AQI:46 details	21 AQI:156 details	22 AQI:93 details
23 AQI:84 details	24 AQI:39 details	25 AQI:77 details	26 AQI:27 details	27 AQI:43 details	28 AQI:115 details	29 AQI:122 details
30 AQI:61 details	31 AQI:44 details					

Historical Data

Year: 2005 Site: All Sites View
Month: July Pollutant: Maximum AQI

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					01 AQI:154 details	02 AQI:100 details
03 AQI:126 details	04 AQI:119 details	05 AQI:87 details	06 AQI:100 details	07 AQI:64 details	08 AQI:49 details	09 AQI:115 details
10 AQI:115 details	11 AQI:150 details	12 AQI:208 details	13 AQI:77 details	14 AQI:64 details	15 AQI:74 details	16 AQI:61 details
17 AQI:84 details	18 AQI:100 details	19 AQI:61 details	20 AQI:156 details	21 AQI:177 details	22 AQI:179 details	23 AQI:80 details
24 AQI:80 details	25 AQI:185 details	26 AQI:204 details	27 AQI:174 details	28 AQI:87 details	29 AQI:74 details	30 AQI:105 details
31 AQI:87 details						

Historical Data

Year: 2010 Site: All Sites View
Month: July Pollutant: Maximum AQI

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					01 AQI:154 details	02 AQI:100 details
03 AQI:126 details	04 AQI:119 details	05 AQI:87 details	06 AQI:100 details	07 AQI:64 details	08 AQI:49 details	09 AQI:115 details
10 AQI:115 details	11 AQI:150 details	12 AQI:208 details	13 AQI:77 details	14 AQI:64 details	15 AQI:74 details	16 AQI:61 details
17 AQI:84 details	18 AQI:100 details	19 AQI:61 details	20 AQI:156 details	21 AQI:177 details	22 AQI:179 details	23 AQI:80 details
24 AQI:80 details	25 AQI:185 details	26 AQI:204 details	27 AQI:174 details	28 AQI:87 details	29 AQI:74 details	30 AQI:105 details
31 AQI:87 details						

Historical Data

Year: 2015 Site: All Sites View
Month: July Pollutant: Maximum AQI

Sun	Mon	Tue	Wed	Thu	Fri	Sat
			01 AQI:101 details	02 AQI:73 details	03 AQI:80 details	04 AQI:64 details
05 AQI:68 details	06 AQI:52 details	07 AQI:87 details	08 AQI:65 details	09 AQI:45 details	10 AQI:67 details	11 AQI:58 details
12 AQI:100 details	13 AQI:71 details	14 AQI:74 details	15 AQI:54 details	16 AQI:58 details	17 AQI:64 details	18 AQI:74 details
19 AQI:87 details	20 AQI:93 details	21 AQI:58 details	22 AQI:54 details	23 AQI:90 details	24 AQI:93 details	25 AQI:100 details
26 AQI:87 details	27 AQI:67 details	28 AQI:100 details	29 AQI:55 details	30 AQI:58 details	31 AQI:90 details	

Historical Data

Year: 2020 Site: All Sites View
Month: July Pollutant: Maximum AQI

Sun	Mon	Tue	Wed	Thu	Fri	Sat
			01 AQI:54 details	02 AQI:48 details	03 AQI:74 details	04 AQI:166 details
05 AQI:68 details	06 AQI:87 details	07 AQI:53 details	08 AQI:52 details	09 AQI:43 details	10 AQI:38 details	11 AQI:45 details
12 AQI:54 details	13 AQI:54 details	14 AQI:58 details	15 AQI:87 details	16 AQI:49 details	17 AQI:90 details	18 AQI:100 details
19 AQI:61 details	20 AQI:77 details	21 AQI:108 details	22 AQI:77 details	23 AQI:93 details	24 AQI:47 details	25 AQI:67 details
26 AQI:58 details	27 AQI:71 details	28 AQI:50 details	29 AQI:119 details	30 AQI:97 details	31 AQI:42 details	

Use the information in these calendars to fill in the table below:

Year	Green Days	Yellow Days	Orange Days	Red Days	Purple Days
1995					
2000					
2005					
2010					
2015					
2020					

Data Analysis

Use the information in the table to look for trends in the data. In other words, have the number of different AQI days changed over time for each color?

The number of green days has ______________________________

The number of yellow days has ______________________________

The number of orange days has ______________________________

The number of red days has ___________________________

The number of purple days has ______________________________

Conclusions

Based on your data analysis, how would you say the level of air pollution in the Washington, DC area in July has changed since 1995? In your answer, be sure to use data and your analysis to support your conclusion.

Activity 7 (Explore): Air Pollution Trends and the Clean Air Act

ACTIVITY DETAILS

Time: 1-2 class periods

Objectives
- ✓ Students will interpret graphs to determine how air quality in the US has changed over time
- ✓ Students will use the Clean Air Act to discuss whether humans have a positive or negative impact on the planet

Materials
- ✓ Computer & projector
- ✓ Speakers (for video)
- ✓ Pollutant trends graphs

Handouts
- ✓ Air Pollution Summary Sheet
- ✓ How Much Pollution is Too Much? (optional)

Activity summary: In this activity, students use graphs based on EPA data to analyze national and regional trends in the 6 Criteria Pollutions defined by the Clean Air Act. In the second half of the activity, students learn more about the Clean Air Act and how humans can have a positive impact on the environment.

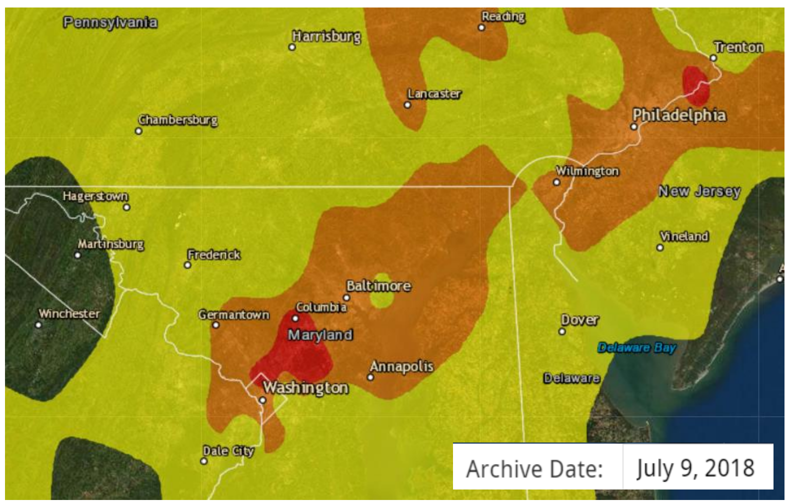
<u>Standards Connection</u>

DCI: ESS 3.C – Human Impacts on Earth's Systems

SEP: Obtaining, Evaluating, and Communicating Information

CCC: Patterns

Warmup: Show students the map of the DC/ Baltimore/Philadelphia area below and tell them that it is a map of the area on the Code Red Day (July 9, 2018).



Questions:

1. Where is the AQI unhealthy or unhealthy for sensitive groups on this map? (between Washington and Philadelphia)
2. Why do you think the AQI is bad in this area (because there are a lot of people in DC, Baltimore, and Philadelphia; because there is a lot of transportation between these cities)

If students struggle with Question 2, have them consider what the land might be like between Washington and Philadelphia as opposed to western Maryland. Is it farmland? Are there a lot of roads? Are there a lot of people?

1. **Frame the activity:** Ask students what they learned in the last activity about how ground-level ozone air pollution has changed in the area over the last 25 years. They should recall that air quality in the region is generally getting better. Next, ask them if they think that's true for other pollutants or other parts of the country. Why? They may have reasons to think that air quality has improved or declined around the country, so give them time to share their ideas. Finally, tell students that during their activity today, they are going to look at a series of graphs to see how air quality has changed over the last 40 years, and then they will learn about why that change has happened.

How Much Pollution Is Too Much?

Optional Literacy & Math Extension

If you have time, consider using this literacy and math extension here. It will help build students' background knowledge about the EPA and the pollution limits, and also improve their understanding about scale, quantity, and proportion. The directions are below, and the handout is at the end of the activity.

Hand out the reading "How Much Pollution Is Too Much?" Provide a reading strategy to help students identify key ideas and questions they have. For example, have students highlight the key ideas, and put a question mark by things they want to ask about. When students are done reading, have them share key points, and use peer discussion to help answer their questions.

Animated Part-per-million (optional). Show students the animated video "How to Visualize One Part Per Million" found at: https://www.youtube.com/watch?v=aa-m8a-jZok

Review the table of pollutants and limits with students, and then have them do the first math problem. Support as necessary in comparing the fractions. Then read the second problem together. Have them setup the problem on their own or with a partner, and then have them do the calculations on their own. Review together as a class.

2. **Air pollution Over Time:** There are two different options for how to do this activity, based upon time, logistics, etc. In both options, student groups will look at graphs of how the criteria pollutants have changed over time, and answer a few questions about each graph. Adapt the directions below based upon which option you choose.
   - Option 1 (Stations). Student groups travel to each station, study all pollutants, and answer all the questions themselves.
   - Option 2 (Expert Groups). Each group studies one pollutant, answers the questions for their pollutant, and then each group presents their answers to the class so all groups get all the answers.

TEACHER NOTES

Tech-integration

- ✓ The air pollution trends graphs are easily accessible on the EPA website. Instead of printing out the maps, have students look at them online using the EPA's air trends page: https://www.epa.gov/air-trends

TEACHER NOTES

Modification

✓ For the Air Pollution Over Time activity, instead of stations, keep materials in folders and pass the folders from group to group instead of having students move.

Teacher Tip

✓ For more information on how to interpret the trends graphs, go to: https://www.epa.gov/air-trends/air-quality-trends-how-interpret-graphs

Modification

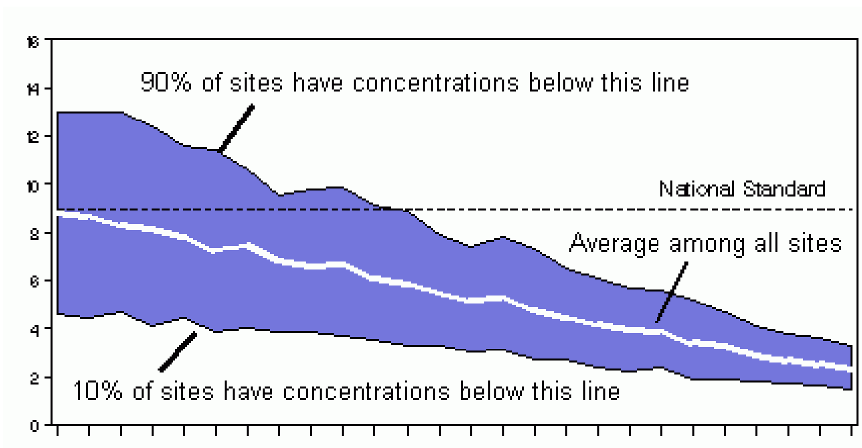
✓ The trends graphs at the bottom of each page show the trends for the NE region and the SE region of the US. Graphs for all other US regions are available from the EPA pollution trends pages: https://www.epa.gov/air-trends

Hand out the air pollution summary sheet. The sheet has the six criteria pollutants listed, and a few questions to answer about each one:

- What is the EPA limit for this pollutant?
- How has the amount of this pollutant changed over time?
- Is this pollutant still a problem where we live? (NE region or SE)

Display the sample graph below so all students can see it, and go over the information it contains. The important things to point out are:

- The National Standard (dotted line). This is the same as the EPA limit. Make sure to show students how to read the y-axis for this measurement
- The average for all places where they collected data (the white line)
- The range that includes 80% of all sites (the blue area)



The graphs that students will be using also have a statistic that describes the trend over time.

If you think it is necessary, you can use the ozone trends graph as an example for students.

Review the directions with students for how they will collect and/or share their data. When you are confident that students understand how to read the graphs, and fill in their summary sheets, release them to begin their research. Most of the information students get from the graphs is straightforward, but they may need help using the scales if they have decimals.

When students have finished all stations, or presented their research to the rest of the class, begin the summarizing section below.

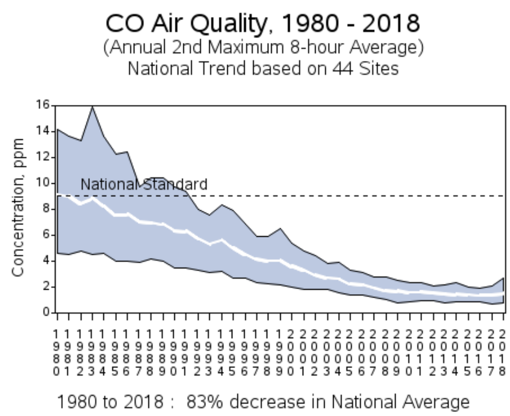
3. **Summarizing Patterns in Air Pollution Trends.** Ask students to consider their predictions from earlier in class. Were they right or wrong? Most students are surprised to find out that air pollution has dropped

significantly in the last 40 years. There are a variety of other summarizing questions you can ask students such as:

- Which pollutant dropped the most? (lead)
- What pollutants are still the biggest problems (ozone and PM)
- Do these graphs mean that air quality is good everywhere? (no – use this as an opportunity to point out that the blue line shows were 80% of the data fall. 10% of the data sites had pollution above the line, so there are still some places where pollution is bad – we call this hyperlocal pollution)

Feel free to add your own summarizing questions to this list. This is also a good time to revisit the class definition of "air quality" if necessary to include the idea that air has better quality when it is below the EPA limit.

4. **The Clean Air Act:** Display one of the air pollution graphs (such as Carbon Monoxide) and ask students why the think air quality dropped so dramatically in the United States.



Students may remember that you mentioned The Clean Air Act in Activity 4, or they may say that the EPA sets rules for how much pollution can go into the air. Remind students that their graphs began in 1980. Based on the trends in the graph, what do they think the air pollution was like in 1970 (it was even worse). Ask students what they would have done if they were alive in 1970 and the air was very unsafe to breathe? They may say things like they would protest or stay inside. Tell students that people in the 1960s were very upset about air quality and water quality, so they decided to do something about it.
Tell students that you are going to show them a video about what people did to fix the problem of air pollution. While they watch, they should look for things that people did to have a positive impact on the planet. Show students the video: "The Clean Air Act of 1970"
https://www.youtube.com/watch?v=yk8NN4nNgs4

Note: some parts of the video will likely be over students' heads, but there are some powerful images and concepts that make it worthwhile.

TEACHER NOTES

The US Without the Clean Air Act

- ✓ This short video simulates what US cities would be like without the Clean Air Act. It can be a powerful visual to show students about how we can have both a positive and negative impact on the planet: https://www.youtube.com/watch?v=8s5kRxFwssw)

- ✓ This old video about air pollution (made in 1962) shows just how bad the air pollution actually was: https://www.youtube.com/watch?v=hBAFjjwcn3g

TEACHER NOTES

Connections to current events

- ✓ Students may make connections between protests that they see in the video with protests that they see today (climate change, BLM, etc.). These are important and valuable connections for them to see about how people can advocate for change. With this said, be mindful of the fact that some of these movements are very different, and require thoughtfulness when leading the discussion.

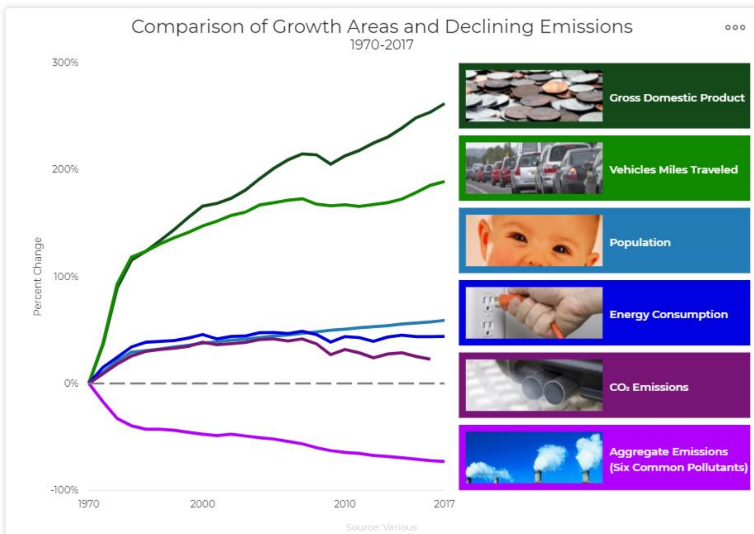
Modification

- ✓ To have this discussion, you may choose to have students form a circle so they can talk directly to one another and debate their positions.

After the video, ask students what things they heard or saw people doing to have a positive impact on the planet. Some things they may say:

- They held protests (dressed up, made signs, marched, etc.) and held the first Earth Day
- They wrote about pollution (ex. Rachel Carson's book Silent Spring)
- The passed laws to protect the environment (the Clean Air Act)
- They worked together

If you find it useful, you can also choose to show students this graph, which shows how successful the Clean Air Act has been, despite the fact that we drive more, use more energy, and have a larger population than we did in 1970.



Source: US EPA

5. **Do humans have a positive or negative impact on the environment?** Now that they have learned about air pollution, trends in air quality, and the Clean Air Act, ask students if they think humans have a positive or negative impact on the environment. Have them start by turning to a partner to discuss what they think. There are many good points to be made on each side. Humans have done a lot of environmental damage, but we have also done a lot to clean up the environment. After students have been able to discuss with a partner, bring the whole class back together to discuss. Allow students to drive the debate, but use questioning to push their thinking.

You may also want to display the air quality map at IQAir: https://www.iqair.com/air-quality-map to remind students that the US air quality used to be like it is now in China and India. The Clean Air Act changed that. What do they think people in China and India are doing right now to begin cleaning up their air?

6. **Return to the Investigation Tracker:** Have students make notes in their investigation tracker based on big ideas they learned during this activity. Key takeaways:
    - Air quality in the United States has improved a lot since 1980.
    - The Clean Air Act was a very important law that helped the US to clean up the air
    - People can have positive and negative impacts on the environment by polluting, or by working to stop pollution

7. **Formative Assessment.** Is the air in the United States safe to breathe? Use the research you gathered about air pollution during class today to support your answer.
    - Student responses will vary, but the important thing to note is how students use the data from the graphs to support their answers. For example, they may say no because ozone is still high, but they may also say yes because most of the criteria pollutants are below the national standard. Students may also say it is safe in some places but not others.

Homework idea

From *Air, Air Everywhere* curriculum (Wisconsin): Have students interview an older family member (ex. grandparent) about their experience with air pollution as a child. Then have them compare it to their own perspectives to see how times have changed. Students can then share what they learned with their classmates.

Find the activity and interview questions here titled "Clean Air – How Far We've Come"
http://eeinwisconsin.org/Files/eewi/2020/Air,Air,EverywhereActivity5CleanAir-HowFarWeveCome.pdf

TEACHER NOTES

Extension

- ✓ This discussion about whether humans have a positive or negative impact on the environment can easily be extended if you have the time to dig deeper. For example, is it considered a positive impact if we simply stop doing something that has a negative impact? What about conservation efforts? Consider what source materials students might need to more fully explore this issue.

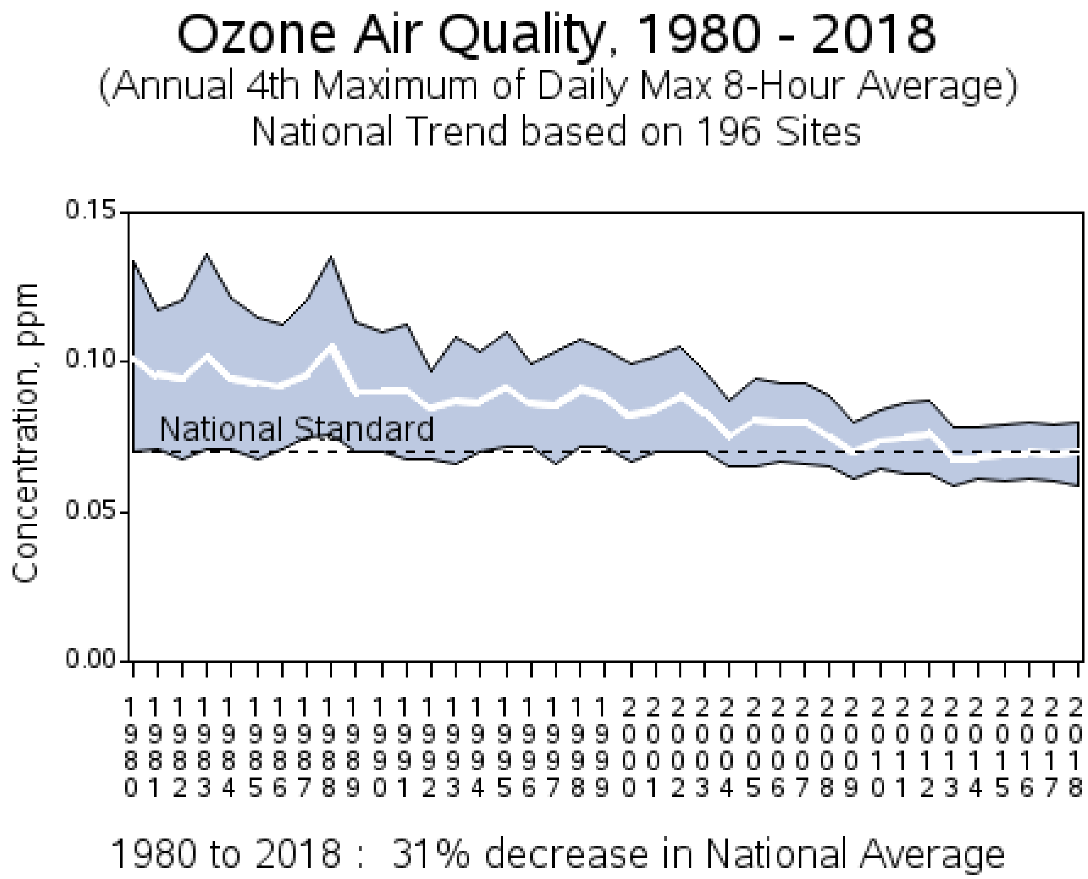
STUDENT HANDOUT

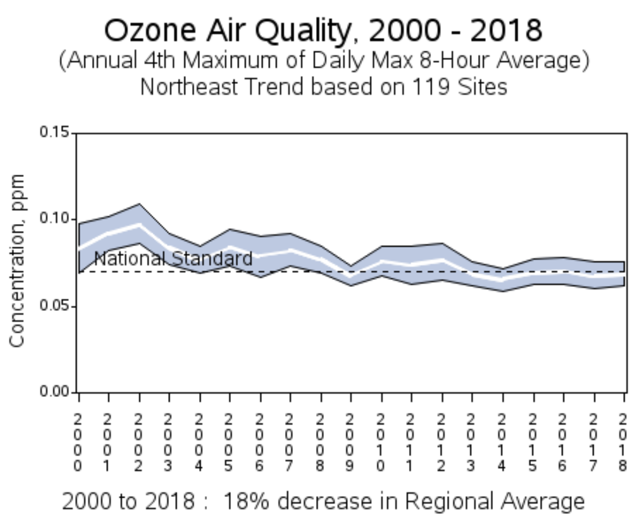
Name ______________________________

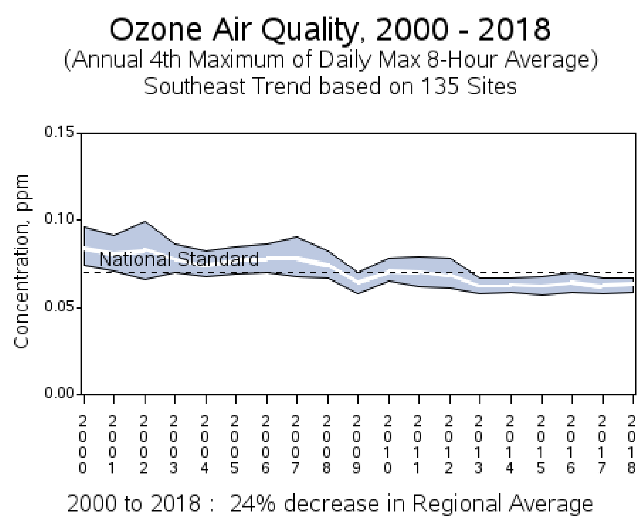
Air Pollution Summary

Pollutant	What is the EPA limit for this pollutant?	How has the amount of this pollutant changed since 1980?	What was the level of this pollutant in 2018?	Is this pollutant still a problem where we live?
Ground-level Ozone				
Carbon monoxide				
Nitrogen dioxide				
Sulfur dioxide				
Particulate matter 2.5		(since 2000 for this graph)		
Lead		(since 2000 for this graph)		**Use national graph data**

Ground-Level Ozone Trends



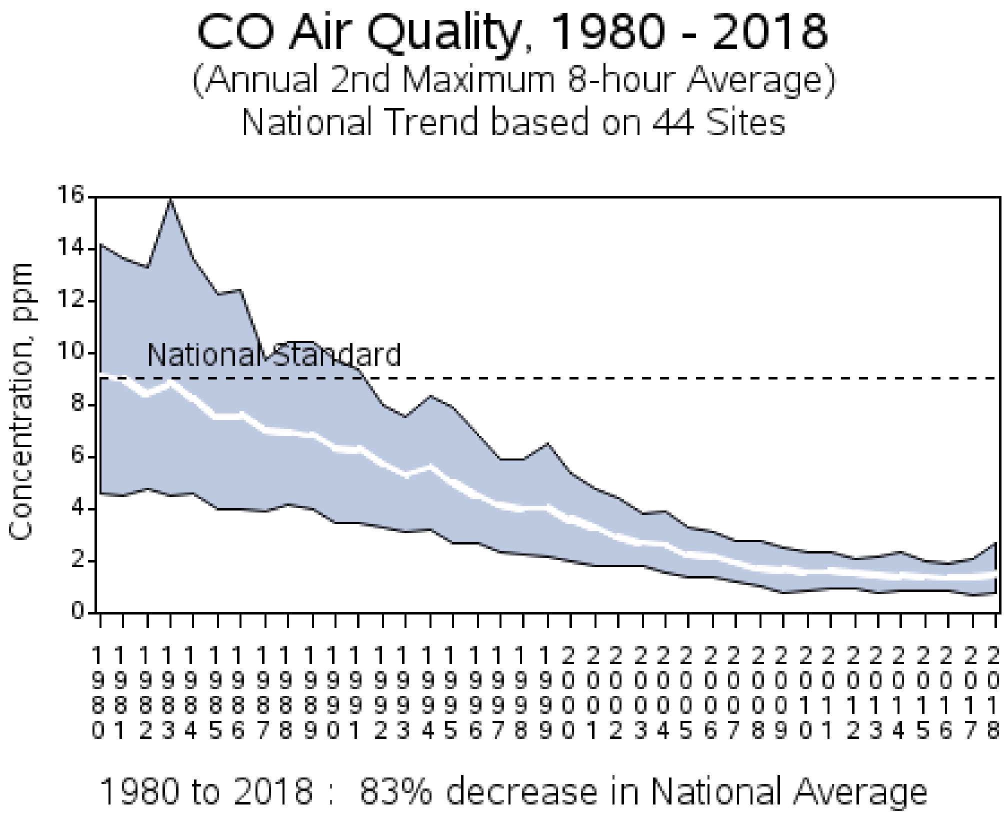


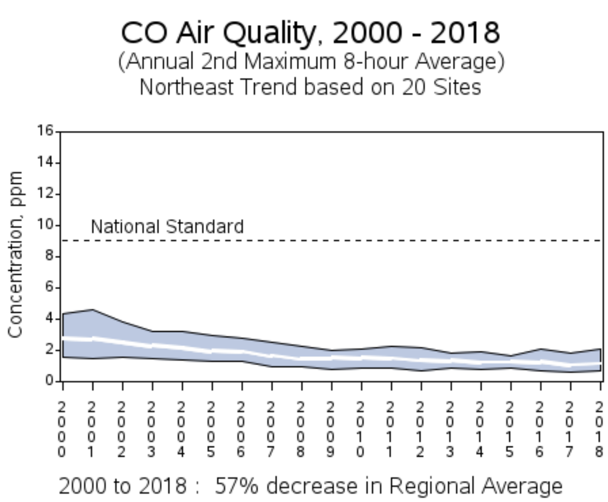


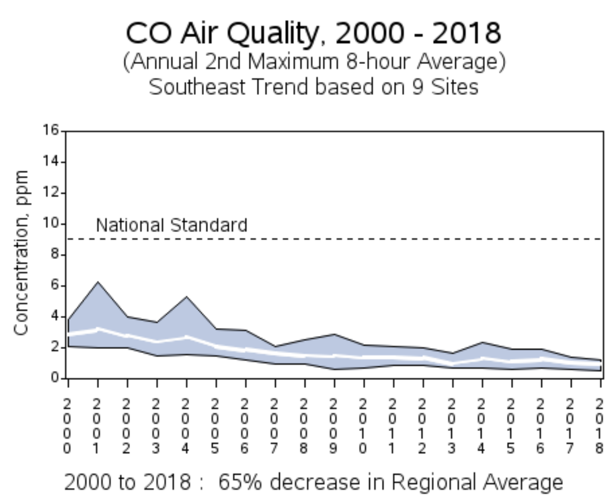
Northeast: ME, NH, VT, MA, RI, CT, NY, NJ, PA, DE, MD **Southeast: VA, NC, SC, AL, GA, FL**

Source: https://www.epa.gov/air-trends/ozone-trends

Carbon Monoxide Trends





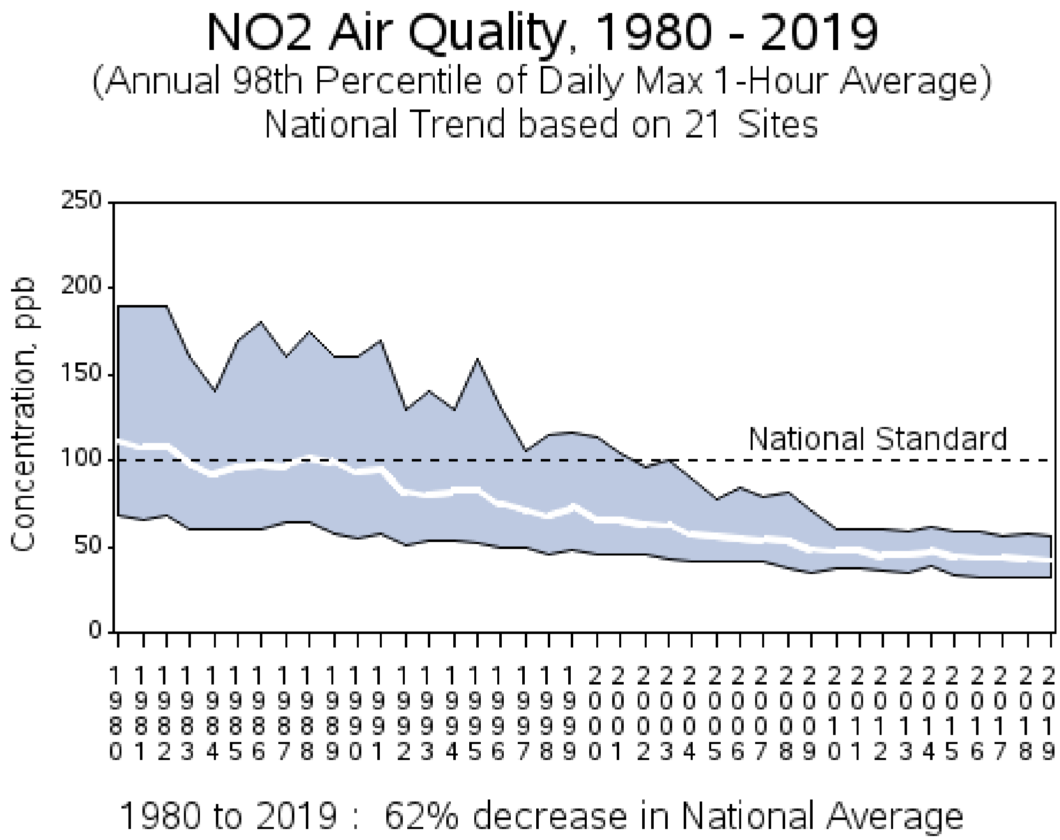


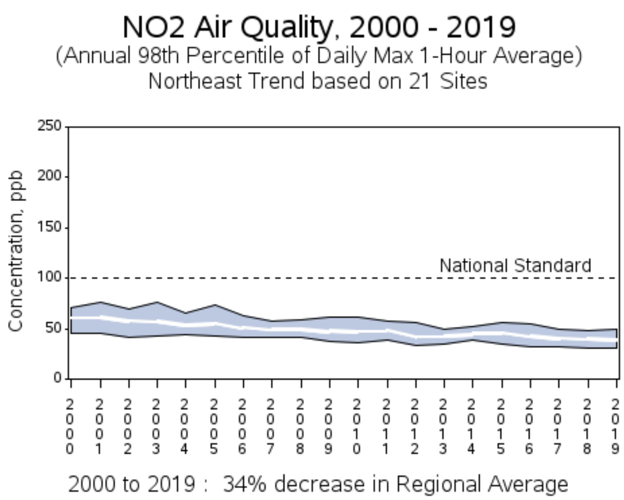
Northeast: ME, NH, VT, MA, RI, CT, NY, NJ, PA, DE, MD

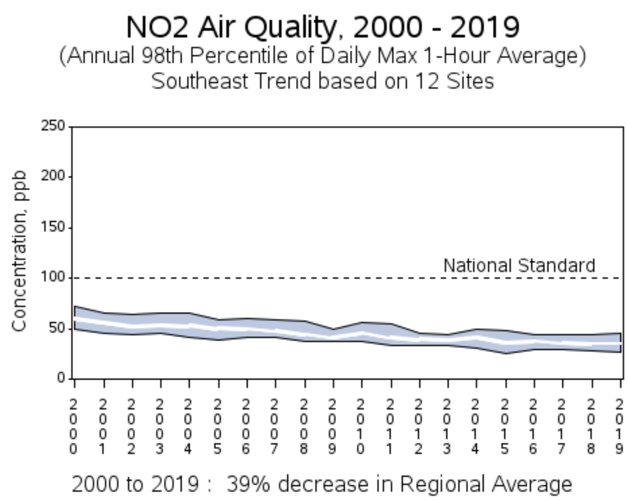
Southeast: VA, NC, SC, AL, GA, FL

Source: https://www.epa.gov/air-trends/carbon-monoxide-trends

Nitrogen Dioxide Trends





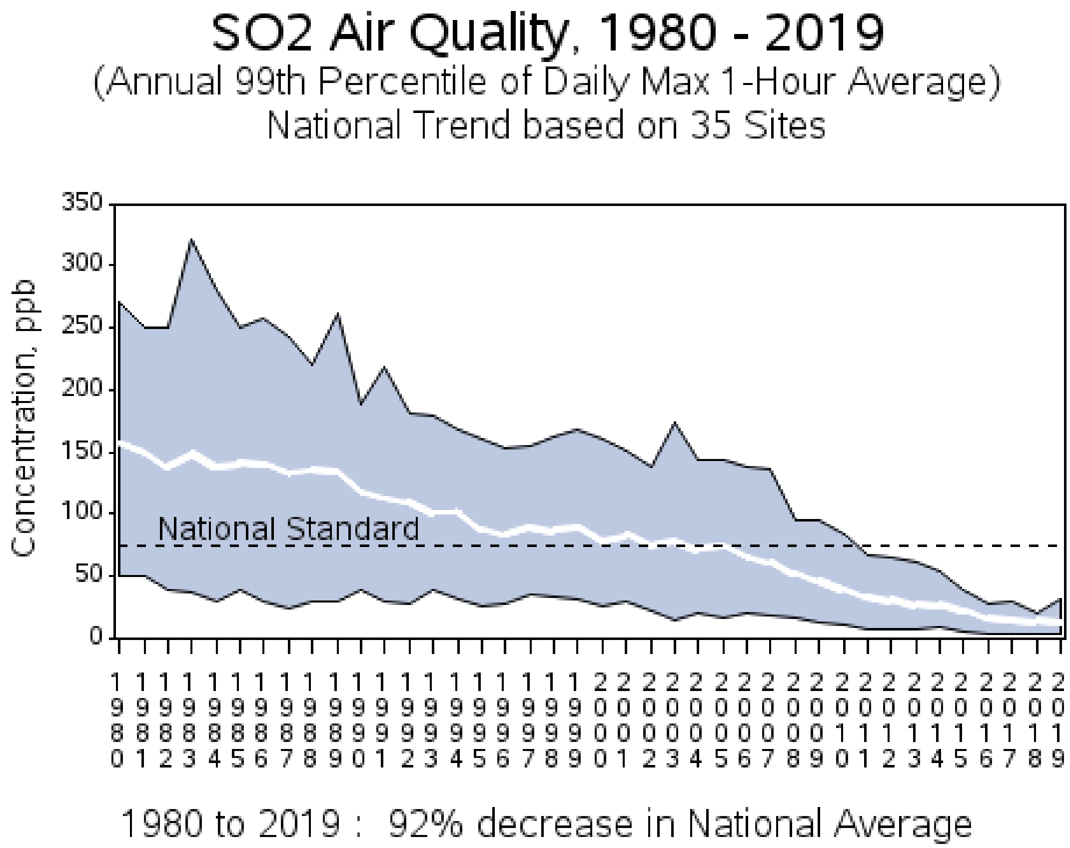


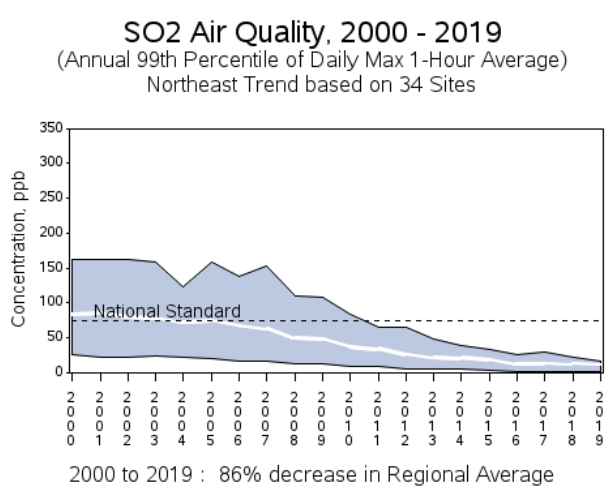
Northeast: ME, NH, VT, MA, RI, CT, NY, NJ, PA, DE, MD

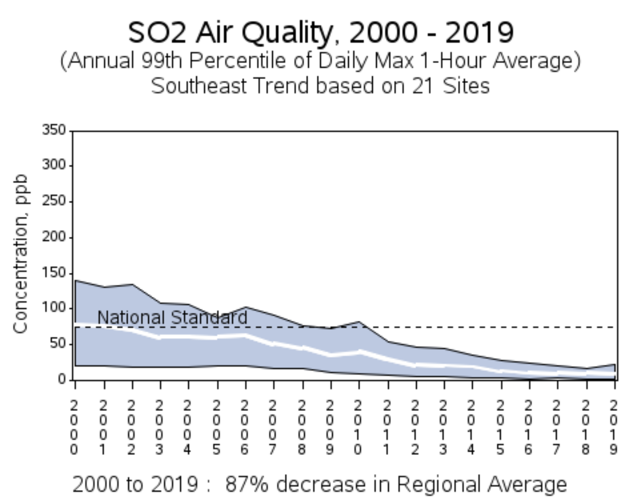
Southeast: VA, NC, SC, AL, GA, FL

Source: https://www.epa.gov/air-trends/nitrogen-dioxide-trends

Sulfur Dioxide Trends





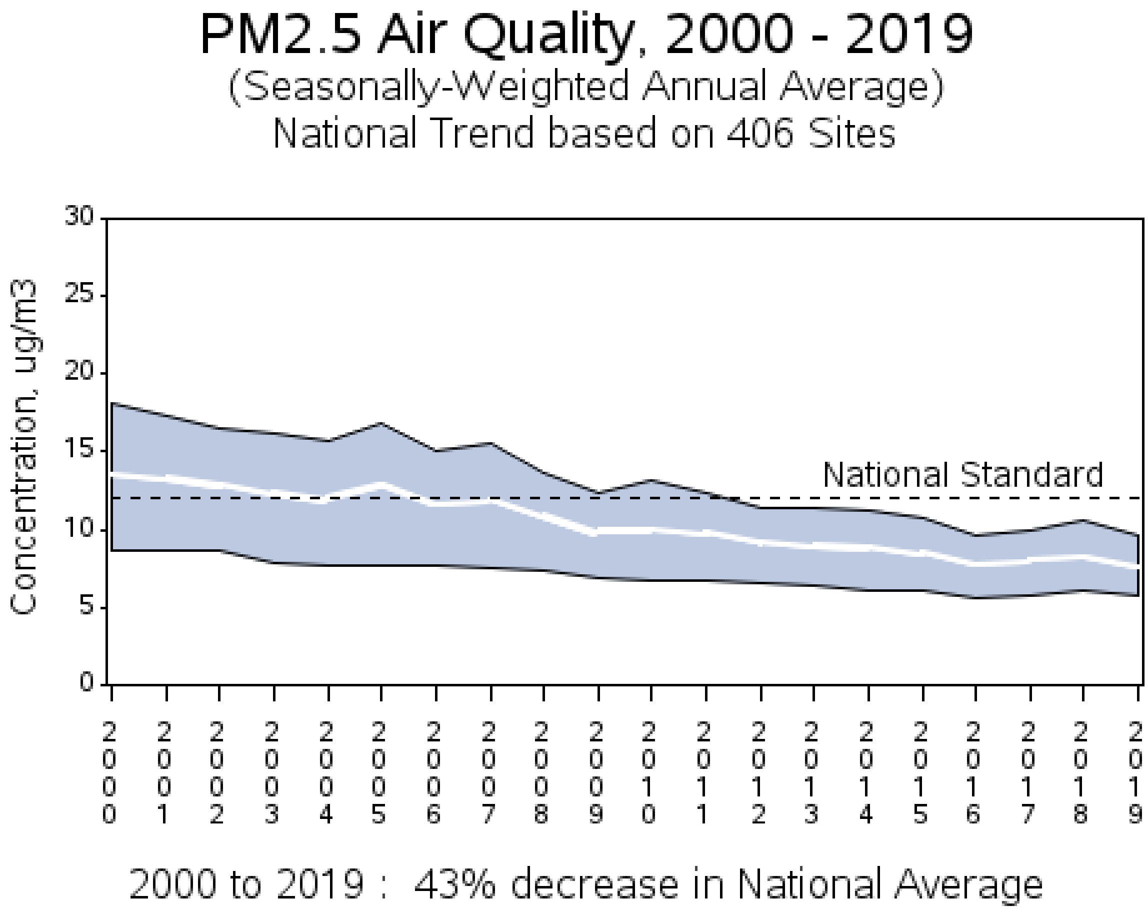


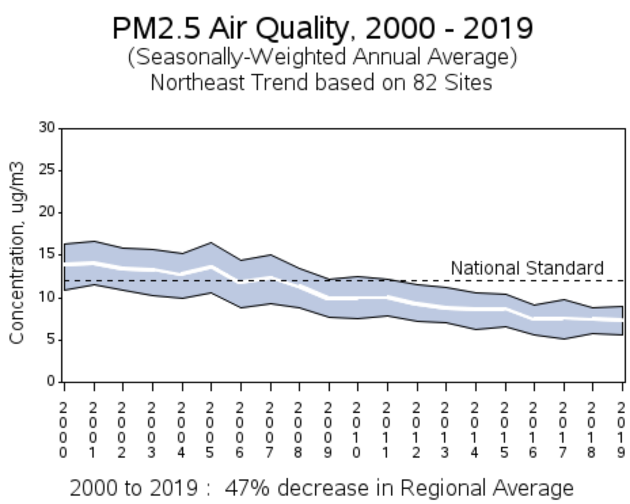
Northeast: ME, NH, VT, MA, RI, CT, NY, NJ, PA, DE, MD

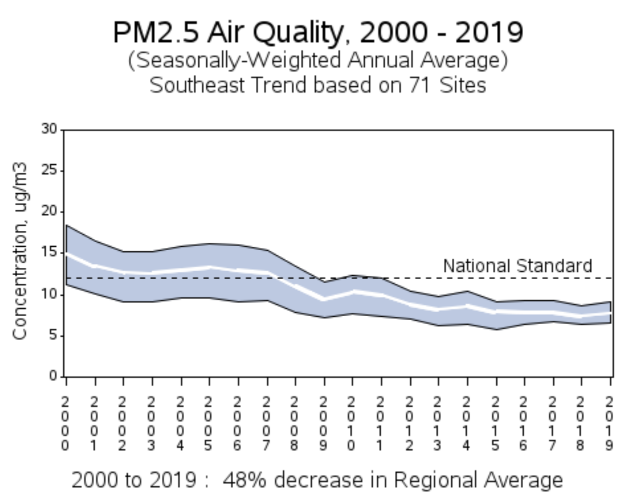
Southeast: VA, NC, SC, AL, GA, FL

Source: https://www.epa.gov/air-trends/sulfur-dioxide-trends

Particulate Matter 2.5μ Trends





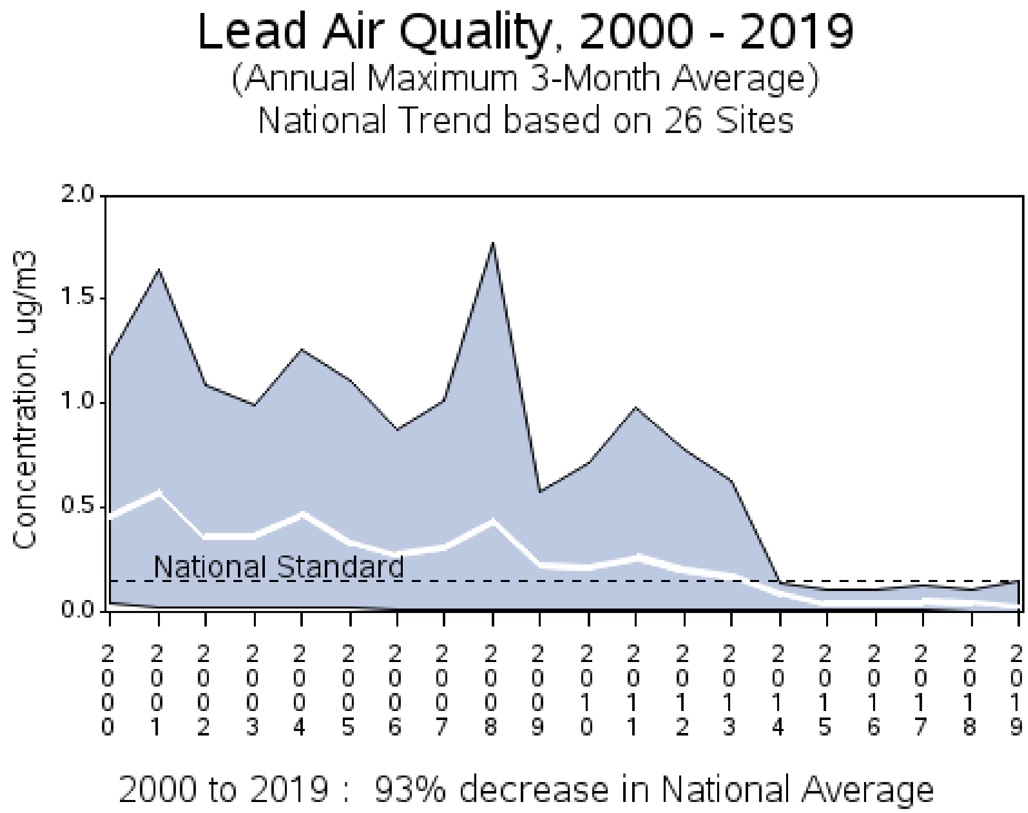


Northeast: ME, NH, VT, MA, RI, CT, NY, NJ, PA, DE, MD

Southeast: VA, NC, SC, AL, GA, FL

Source: https://www.epa.gov/air-trends/particulate-matter-pm25-trends

Lead Trends



Source: https://www.epa.gov/air-trends/lead-trends

Name ______________________________

STUDENT HANDOUT

How Much Pollution Is Too Much?

The United States Environmental Protection Agency (EPA) is a part of the government that is responsible for making sure the air we breathe is safe. Scientists at the EPA decide how much pollution in the air is harmful to human health or the environment. It would be safest if there were no pollution in the air at all, but many of the things we like to use such as cars and computers either make pollution, or use electricity that is often made in way that creates pollution. For example, gasoline-powered cars create air pollution, and power plants that burn fuel to make electricity also make air pollution.

The EPA sets limits for the amount of air pollution that is harmful people to breathe into their lungs. There are different limits for each kind of air pollution based on how harmful each kind of pollution is. Very harmful pollutants have very low limits because even very, very small amounts of these chemicals can be harmful. The units that the EPA uses for these limits are "parts-per-million" or ppm and "parts-per-billion" or ppb. These are units just like inches or miles or meters. One part-per-million means one molecule of pollution in 1 million molecules of air.

How many is one part-per-million? Think how long one day is. One day in a million days is the same as one day in 2,737 years!

How about one part-per-billion? Imagine an Olympic-sized swimming pool like the one in the picture below. One part-per-billion is the same as one drop of water in the whole swimming pool.

One part-per-billion

We can also write units such as percent, parts-per-million and parts-per-billion as fractions to help compare them. Look at the three fractions below:

1 percent (1%) = $\frac{1}{100}$ 1 ppm = $\frac{1}{1{,}000{,}000}$ 1 ppb = $\frac{1}{1{,}000{,}000{,}000}$

One percent pollution would mean 1 molecule of pollution for every 100 molecules of air. 1 ppm is 1 molecule of pollution for every 1,000,000 molecules of air, and 1 ppb is 1 molecule of pollution for every 1,000,000,000 molecules of air.

Even though these amounts of pollution seem very small, they can have a big effect because humans breathe so much air. The average human breathes 10,000 liters of air a day, so even small amounts of pollution can cause a big problem for us.

How much pollution is too much? The EPA limits for a few common air pollutants are shown in the table below:

Pollutant	Limit of "safe" amount	Limit in fraction form
Sulfur dioxide	75 parts-per-billion (ppb)	$\frac{75}{1,000,000,000}$
Nitrogen dioxide	100 parts-per-billion (ppb)	$\frac{100}{1,000,000,000}$
Carbon monoxide	9 parts-per-million (ppm)	$\frac{9}{1,000,000}$
Ozone	75 parts-per-billion (ppb)	$\frac{75}{1,000,000,000}$

Compare the EPA limits for the four different pollutants listed. The write them in order from smallest to largest, using the symbols >, <, and =. Label each one using the ppm and ppb notation.
The average human breathes 10,000 liters of air a day (2,641 gallons). If you breathe 10,000 liters of air in a day, how many liters of ozone would you breathe **in a year** if the air had the EPA limit of ozone in it?

Compare the EPA limits for the four different pollutants listed. The write them in order from smallest to largest, using the symbols >, <, and =. Label each one using the ppm and ppb notation. $$\frac{9}{1{,}000{,}000} > \frac{100}{1{,}000{,}000{,}000} > \frac{75}{1{,}000{,}000{,}000} = \frac{75}{1{,}000{,}000{,}000}$$ 9pmm > 100 ppb > 75 ppb = 75 ppb Carbon monoxide nitrogen dioxide sulfur dioxide ozone
The average human breathes 10,000 liters of air a day (2,641 gallons). If you breathe 10,000 liters of air in a day, how many liters of ozone would you breathe **in a year** if the air had the EPA limit of ozone in it? $$\frac{10{,}000\ liters\ of\ air}{day} \times \frac{75\ liters\ of\ ozone}{1{,}000{,}000{,}000\ liters\ of\ air} \times \frac{365\ days}{year} =$$ $$0.27\ liters\ of\ ozone\ per\ year$$

Activity 8 (Elaborate): Smog City: How Weather Affects Air Quality

ACTIVITY DETAILS

Time: 45 minutes

Objectives

- ✓ Students will understand how different weather conditions affect AQI
- ✓ Students will understand how emissions from various sources and population affect AQI

Materials

- ✓ Computer & projector
- ✓ Student computers (highly recommended)

Handouts

- ✓ Save Smog City from Ozone!

Teacher Tip

- ✓ Ideally, students will do this activity on their own or in pairs using student computers. If computers are not available, the activity can be done together as a class using a projector.

Activity summary: This activity is based on the EPA's air quality and weather simulation "Smog City 2". After a brief introduction to the simulation, students explore how different variables centered around emissions, weather, and population affect air quality. This if followed by a discussion to summarize what they learned from the simulation.

Standards Connection

DCI: ESS3.C – Human Impacts on Earth Systems
DCI: ESS2.D – Weather & Climate
SEP: Developing & Using Models
CCC: Patterns; Systems & System Models

Important Technology Note about this Activity

Smog City 2 uses Flash, which is not supported in newer browsers. You will need to click the option to allow Flash to run in your browser in order to launch Smog City. If this does not work, you may need to use a downloaded copy, so be sure to try the simulation out on student computers before using it with a class. You can download a copy of Smog City 2 by signing up here: http://www.smogcity2.org/download.cfm

Warmup: Have students take out the visual glossary they created in Activity 2. Then have them describe today's weather today using these scientific terms. Students may look up the details using computers (which will be used today) or from a handout/ projection of a current weather report.

1. **Frame the activity:** Remind students that for this investigation they have taken on the role of meteorologists. So far in the investigation, they have been learning how to explain the weather. Now that they understand more about how weather and air pollution work, it is time for them to learn how to predict the air pollution so that they can keep people in the community safe from air pollution. To do this, they need to understand how weather affects air quality. Today they are going to use a computer simulation of a real city to see how weather affects air quality.

2. **Smog City 2.** Display the Smog City simulation on a projector where all students can see it: http://www.smogcity2.org/

   Show students how to launch the simulation, and briefly review the controls with them. Pass out the Save Smog City from Ozone! sheets and student computers. Then support students in following the directions on the handout and answering the questions.

3. **Smog City Summary Discussion.** Lead a discussion with students on how different weather factors affect the level of pollution. Create an anchor chart based on students' responses that you can leave up in the room (this will help with later activities in the module). As students answer, ask why they think this weather factor changes the AQI in the way it does. Make sure to leave room at the bottom to add other factors.
   - Sky condition/cloud cover: more clouds = lower AQI because there is less sunlight to generate ozone
   - Wind: more windy = lower AQI because the ozone is blown away
   - Inversion (optional): an inversion = higher AQI because pollution is trapped near the surface
   - Temperature: higher temperature = higher AQI because the chemical reaction that makes ozone goes faster (this is generally true but not always)

4. **Additional Weather Factors**: Remind students that there are a few other weather factors from their glossary that may also affect air pollution. Ask students how they think the following factors affect air pollution and why. As they discuss, add these to the anchor chart:
   - Precipitation: more precipitation = lower AQI because the precipitation essentially washes out the pollution
   - Humidity (optional): higher humidity = lower AQI because it helps O_3 to convert back to O_2

5. **Return to the investigation tracker:** Have students make notes in their investigation tracker based on big ideas they learned during this activity. Key takeaways:
   - Air pollution (especially ozone) is strongly affected by the weather
   - Weather conditions like clear sunny skies and low wind are more likely to result in a bad ozone day
   - Rain can "wash" pollution out of the air resulting in less ozone.
   - Large human populations can result in more emissions and worse air quality if they don't do something to prevent it

TEACHER NOTES

Teacher Tips

- ✓ In general, increased temperatures cause higher AQIs. The Smog City 2 simulation includes some complex modeling that makes this somewhat unclear. It is helpful to simplify this during the discussion.

Differentiation

- ✓ Pair students for the simulation in a way that allows more advanced students to support struggling students.

Modification

- ✓ Use an alternative discussion technique to engage students after the simulation. For example, have students stand up and move to one side of the room based on whether they think the variable will make the AQI go up or down, and have each side make an argument based on where they moved.

TEACHER NOTES

Research sources

- ✓ If you are keeping track of research sources, you can add Smog City to the list for ways to see how different weather conditions affect air quality.

6. **Formative assessment**. Based upon what you learned during with Smog City, what do you think the weather was like on July 9, 2018 – our Code Red Day?
   - Students should suggest low wind, high temperature, clear skies, low humidity, no rain, and possibly an inversion. The actual weather matches this well: (go back to the weather you looked up in Activity 2 for exact information) https://www.wunderground.com/history/daily/us/dc/KDCA/date/2018-7-9
     - High temp: 86°F
     - Fair skies throughout the day
     - Wind speed under 10mph most of the day
     - 0 precipitation

   You can also put up the weather report from the warmup (or have students consider today's weather). Based on this weather, would you expect there to be an ozone problem today?
   - To check students' predictions, you can look up the current ozone information for the DC-Baltimore region by going to https://www.cleanairpartners.net/current-and-forecasted-air-quality and clicking on "current"
   - Generally speaking, the ozone levels will be low unless it is a hot day with little wind and low humidity

Name ______________________________

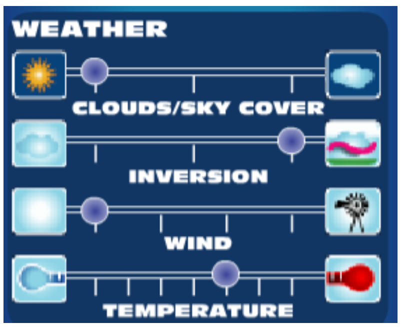
STUDENT HANDOUT

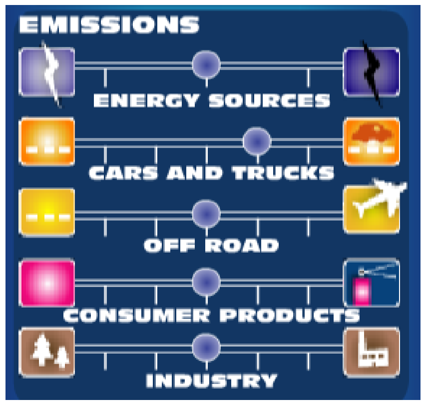
Save Smog City from Ozone!

[Adapted from *Save Smog City 2 From Ozone*]

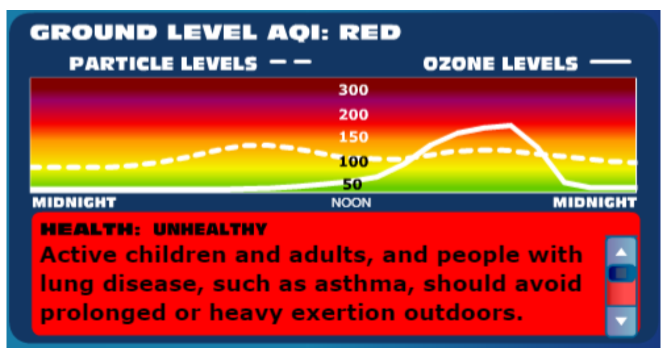
Directions:

1. Go to the website [www.smogcity2.org]
2. Click on the link "Save Smog City 2 from Ozone" in the bottom left
3. Look at your controls on the left side of the screen. You have controls for weather, emissions, and population. Try out the controls to make sure you know how they work.

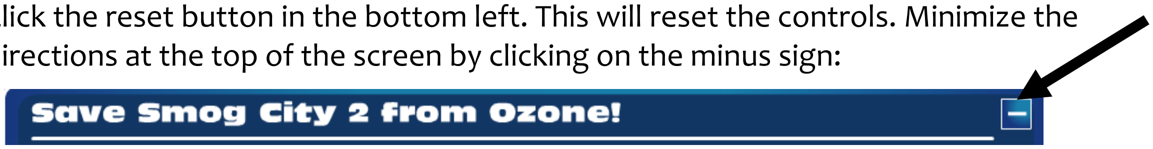




4. Look at the information about air quality you have. Find the temperature and AQI information and the ground-level AQI information:



5. Find the information box at the bottom of the screen. When you click on any of the controls, you will find information about it.
6. Click the reset button in the bottom left. This will reset the controls. Minimize the directions at the top of the screen by clicking on the minus sign:



You're now ready to save Smog City from Ozone!

Scenario 1: Emissions

What is the AQI at the start of the scenario? ______________________

What color does this AQI represent? ____________________________

Change some of the emissions controls. What happens to the AQI when the emissions go up or down?

____

____

Which kind of emissions changes the AQI the most? ___________________________

Why do you think this is? ____

____

____

Change the emissions controls so the AQI is in the yellow zone. Draw your settings on the chart below:

Energy Sources:

Cars & Trucks:

Off Road:

Consumer Products:

Industry:

Now change the emissions controls so the AQI is in the green zone. Draw your settings on the chart below:

Energy Sources:

Cars & Trucks:

Off Road:

Consumer Products:

Industry:

Scenario 2: Weather

Click the reset button in the bottom left to set the controls back to their defaults.
Adjust each of the weather controls, and notice how the AQI changes with the weather. Circle how the AQI changes with each weather change:

When it gets **more cloudy,** the AQI goes up OR goes down (circle one)

When there is a **high altitude inversion** (a layer of warm air), the AQI goes up OR goes down

When there is **high wind**, the AQI goes up OR goes down

When there is **high temperature**, the AQI goes up OR goes down

Find a setting for weather that has an AQI at the green level. Describe what the weather is like:

____

____

____

Find a setting for weather that has an AQI at the red level. Describe what the weather is like:

____

____

____

Look at the graph in the bottom right that shows AQI at different times of day. When is the AQI the worst during the day? ______________ Why do you think this is? ______________________

____

Scenario 3: Population

Click the reset button in the bottom left to set the controls back to their defaults.
Use the population settings to raise and lower the population.

When there is **higher population,** the AQI goes up OR goes down (circle one)

Why do you think population has such a big effect on AQI?______________________

____

____

____

TEACHER GUIDE

Scenario 1: Emissions

What is the AQI at the start of the scenario? 175

What color does this AQI represent? Red

Change some of the emissions controls. What happens to the AQI when the emissions go up or down?

When the emissions go up, the AQI goes up, and when the emissions go down, the AQI goes down

Which kind of emissions changes the AQI the most? Cars and trucks

Why do you think this is? There are a lot of cars and trucks on the road, and they produce a lot of pollution, so reducing the number of cars can have a big effect on the AQI

Change the emissions controls so the AQI is in the yellow zone. Draw your settings on the chart below:

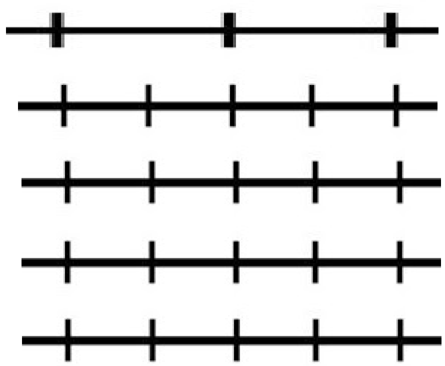
Energy Sources:

Cars & Trucks:

Off Road:

Consumer Products:

Industry:



Answers will vary. Cars and trucks will likely be at the lowest or near lowest level.

Now change the emissions controls so the AQI is in the green zone. Draw your settings on the chart below:

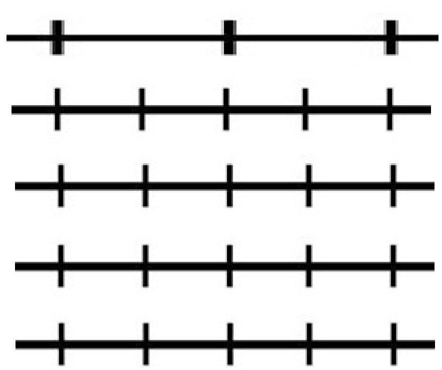
Energy Sources:

Cars & Trucks:

Off Road:

Consumer Products:

Industry:



Answers will vary, but will generally be at or near the lowest levels

Scenario 2: Weather

Click the reset button in the bottom left to set the controls back to their defaults.
Adjust each of the weather controls, and notice how the AQI changes with the weather. Circle how the AQI changes with each weather change:

When it gets **more cloudy,** the AQI goes up OR goes down (circle one)

When there is a **high altitude inversion** (a layer of warm air), the AQI goes up OR goes down

When there is **high wind**, the AQI goes up OR goes down

When there is **high temperature**, the AQI goes up OR goes down

Both are true depending on other weather conditions

Find a setting for weather that has an AQI at the green level. Describe what the weather is like:

Answers will vary, but in general, the weather will be windy, with no inversion. It may be cloudy, and the temperature may be moderately warm

Find a setting for weather that has an AQI at the red level. Describe what the weather is like:

Answers will vary, but in general, the weather will not be windy, and there will be a high-altitude inversion. It may be sunny, and the temperature may be either very cold or very hot.

Look at the graph in the bottom right that shows AQI at different times of day. When is the AQI the worst during the day? In the afternoon Why do you think this is? AQI is worst in the afternoon because it is hotter and the sun is more directly overhead

Scenario 3: Population

Click the reset button in the bottom left to set the controls back to their defaults.
Use the population settings to raise and lower the population.

When there is **higher population,** the AQI goes up OR goes down (circle one)

Why do you think population has such a big effect on AQI? Population has a big effect on AQI because it affects all the other emissions. When there is a bigger population, there are more cars and truck, more electricity is needed, and there are more factories. So population makes all the other emissions factors go up.

Activity 9 (Elaborate): Making an Air Quality Prediction

ACTIVITY DETAILS

Time: 45-60 minutes

Objectives

- ✓ Students will be able to make an AQI prediction using data from a variety of information sources including weather conditions

Materials

- ✓ Computer & projector
- ✓ Student computers (highly recommended)

Handouts

- ✓ AQI prediction guide

Teacher Tip

- ✓ This activity will be more engaging if students have computers to use. If computers are not available, the activity can be done together as a class using a projector.
- ✓ This activity is complex, and students will likely be more successful if they work with a partner, either the whole time, or by checking it at times along the way.

Activity summary: In this activity, students learn how meteorologists make air quality predictions based on air pollution and weather modeling. Then they use what they have learned to make their own an air quality forecast.

<u>Standards Connection</u>

DCI: ESS3.C – Human Impacts on Earth Systems
DCI: ESS2.D – Weather & Climate
SEP: Developing & Using Models; Obtaining, Evaluating, and Communicating Information

Warmup: What kinds of information do you think a meteorologist would need in order to make a weather forecast?

- Students will likely think of what they have learned in the past few activities, but if they are stuck, use prompts to get them started
- Possible answers: temperature, precipitation, wind speed and direction, humidity, etc.

1. **Frame the activity:** Tell students that making a weather prediction depends on knowing what the current weather is like and using that information to make an informed guess as to what will happen next, just like you might make a guess about what will happen next in a movie or a book based on what you've already read. Meteorologists put the weather information into a computer program that models what might happen next. They do the same thing for air quality. Today we are going to be meteorologists and make an AQI forecast for ozone so we can tell people whether to plan for a good or bad air day, just the way professional meteorologists do.

2. **Introduction to AQI Prediction:** Hand out student computers (if available) and the AQI Prediction Guide. Tell students that when a scientist wants to make an air quality prediction, they follow a series of steps. We're going to use steps just like the scientists do to make our own forecast together.

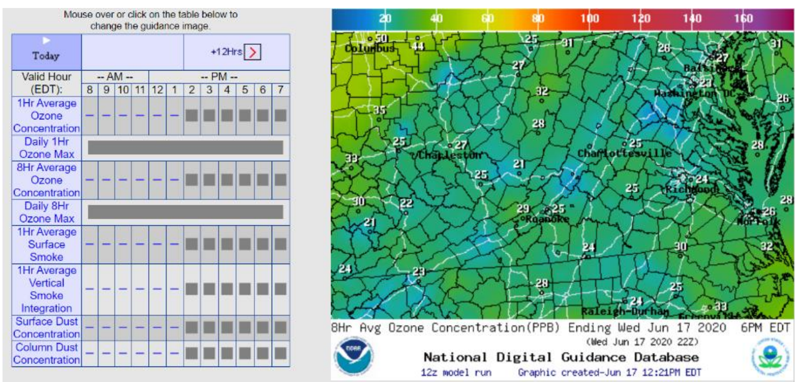
   Preview the parts below with students. Ask students why each part is necessary for their forecast:

   - Part 1: Start with the National Weather Service's (NWS) air quality computer model prediction – *a computer model is needed as a starting point based on the huge amount of air quality data*

- Part 2: Learn about what the weather will be using the National Weather Service's weather forecast – *local weather will affect the air quality*
- Part 3: Adjust the Weather Service's air quality model based on the upcoming weather – *making adjustments based on weather will make the AQI prediction closer to reality*
- Part 4 (optional): Look for any pollution which may be blowing into the area – *a lot of pollution blowing in can affect the AQI*

3. **Part 1: The NWS Air Quality Computer Model:** Start by going to the National Weather Service's computer model of what the air quality will be: airquality.weather.gov. This model takes some variables into account, but it needs to be adjusted for local weather conditions.

   Once you get to the website, click on the area of the area of the map where the school is. Continue clicking until you are zoomed into a state-level view that looks like this:



   Ask students what kind of information they see on the page. Key observations:

   - The map on the right is color-coded for AQI based on a single pollutant (it usually starts with ozone). It also has AQI numbers.
   - The date for this information is at the bottom. It will likely be some time in the future since this is a forecast
   - The left side has a list of different pollutants (ex. ozone, smoke, and dust)
   - The left side also has times of day (AM & PM) and some buttons for changing the time of day

   If you hover over the different gray boxes on the left (make sure "Table MouseOver Effect" is on, you can see the pollution prediction change over time on the map.

TEACHER NOTES

Teacher Tip

- ✓ An important thing to keep in mind during this activity is that the ultimate accuracy of students' AQI predictions is less important than the thought process they go through to make the prediction. With this said, seeing which student(s) can get closest to the actual AQI for the day they are forecasting could be a great motivator for them to try their hardest.

Explicit Language

- ✓ Students are using a lot of computer models in this activity. Be sure to consistently use the word "model" and "modeling" to drive this point home.

Modifications

- ✓ There are a lot of interesting features on the NWS air quality page. For example, the "Loops" tab allows you to watch the map change over time. You and students can explore these other features to learn a lot more about how AQI changes over time.

TEACHER NOTES

Teacher Tip

- ✓ Both the AirNow and the Clean Air Partners websites have predictions for air quality. Students may want to use these sites to adjust their own predictions, and if so, remind them that you want *their* predictions, not the EPA's.

Click on the +12 hour button twice. Ask students why you need to do this (to get to this time tomorrow). Then click on the gray bar for "Daily 8Hr Ozone Max". This will show the maximum ozone prediction (over an 8-hour span) in parts-per-billion that we will use to start our own forecast. Have students use the scale at the top to determine what the ozone levels will be like tomorrow. What is the maximum ozone for the area closest to the school? Have students record this information on their sheets in parts-per-billion. To convert the ozone level to AQI, go to: https://www.airnow.gov/aqi/aqi-calculator-concentration/ and enter the relevant information.

4. **Part 2: NWS Weather Forecast:** Go to the National Weather Service's weather forecast page: https://www.weather.gov. At the top left of the page, there is a place to input your location to get the local forecast. Once on that page, find the **Detailed Forecast** and enter the relevant information on the AQI prediction guide. To find the relative humidity tomorrow (optional), scroll down on the page and click "Hourly Weather Forecast" to bring up a set of line graphs showing the forecast. Find relative humidity and record it for the early afternoon when it is likely to be hottest.

5. **Part 3: Adjusting the forecast based on the weather:** Have students transfer their AQI from Part 1 into the first box of the table. Then have them use what they've learned about how the weather affects AQI to decide if each weather factor will make the AQI go up, stay the same, or go down. Once they've finished filling in the table, they can make a final AQI prediction (number and color). Students may have questions about how much the AQI will change. You can provide some guidance and/or have them think back to the Smog City simulation. The AQI may go up or down from the model, but it won't go from 50 to 100 because of weather adjustments. In reality, meteorologists draw upon years of experience, intuition, and education to make these adjustments, and even they don't always agree on the changes.

6. **Part 4: Adjusting the forecast for incoming pollution (optional extension):** Sometimes events occurring upwind such as wildfires or power plant emissions can affect the air quality in an area. To investigate how incoming pollution might affect the AQI, have students first determine where the air is coming from. They can do this by going to windfinder.com and zooming in on the area where the school is located. Next, have them go to airnow.gov to look up the current AQI in the area where the wind is coming from. They can do this by putting in the school's city, state or zip code. The page that comes up will have a map of the area. If you click on this map, it will bring you to a larger map. Switch the map to show the monitors for ozone using the menu on the left side. From here, you can see if there is any ozone coming into their area based on current wind patterns. If the AQI upwind is particularly bad, students may want to adjust their AQIs up.

7. **Discuss adjustments in small groups:** Once students have made their adjustments to the forecast, have them get together in small groups to discuss what changes they made and talk through why they made their decisions. If some students got stuck on certain parts of the modeling, this will give them a chance to get support from their peers. You can also choose to hold this discussion as a whole group and allow students to debate their adjustments, ex. whether one factor is more important than another in affecting the AQI. While students are discussing (either whole group or small group), listen in and push their thinking, especially to have them explain **why** they made certain adjustments.

   If you think it will provide extra motivation, remind students that you will check to see whose AQI prediction is closest to the actual AQI for the date they are predicting. Some students may enjoy this mini-competition aspect of the prediction process.

TEACHER NOTES

Differentiation

✓ If you teach some advanced students, have them follow the directions for the incoming pollution adjustment as an extension.

Authentic learning

✓ This activity mirrors very closely what actual meteorologists do when preparing an AQI forecast. During "ozone season" in the summer months, meteorologists across the region hold regular phone calls to discuss and debate their daily predictions.

TEACHER NOTES

Modifications

✓

Teacher Tip

✓

8. **Formative assessment.** The next and final activity in this module asks students to create a weather forecast focused on air quality based on what they've learned during this module. That may serve as the formative assessment for this activity. Alternatively, you can provide students with a fictional AQI and weather scenario and have them adjust it using the table like the one in their prediction guide:

Starting AQI (National Weather Service)	The temperature will make the AQI…	The wind will make the AQI…	The precipitation will make the AQI…	The sky condition will make the AQI…	The humidity will make the AQI go…
	Go up	Go up	Go up	Go up	Go up
	Stay the same	Stay the same	Stay the same	Stay the same	Stay the same
	Go down	Go down	Go down	Go down	Go down

Name ______________________________

STUDENT HANDOUT

AQI Prediction Guide

Three parts

- Part 1: Look up the National Weather Service's (NWS) air quality prediction.
- Part 2: Look up the weather forecast from the National Weather Service.
- Part 3: Adjust the Weather Service's air quality prediction based on the weather forecast.
- Part 4 (optional): Check for pollution blowing into the area, and adjust your prediction if necessary

Part 1: The National Weather Service air quality computer model

1. Go to NWS air quality computer model at: airquality.weather.gov
2. Click on the part of the map where you live to zoom in. You will need to click at least twice to get as zoomed in as you can go.
3. Look at tomorrow's forecast by clicking the +12Hrs button twice. You should see tomorrow's day of the week.
4. Click on the gray bar where it says "Daily 8Hr Ozone Max."
5. What does the map show about the ozone levels for tomorrow?

____

____

6. What is the maximum ozone level closest to you? ______________ ppb
7. To covert this to AQI, go to: https://www.airnow.gov/aqi/aqi-calculator-concentration/ and enter the information.
8. What is the AQI for this amount of ozone? ______________

Part 2: The National Weather Service weather forecast

1. Go to the NWS weather forecast page: https://www.weather.gov/
2. At the top left where it says, "Local forecast by "City, ST" or ZIP code, enter your location and click Go
3. Find the **Detailed Forecast** and look at the forecast for tomorrow. Record the necessary information for the forecast:

    - High temperature: ______________
    - Wind speed: ______________ and wind direction: ______________
    - Precipitation: ______________
    - Sky condition: ______________
    - Humidity: ______________
      Note: humidity graph can be found on the graphs for Hourly Weather Forecast under Additional Resources

Part 3: Adjusting the AQI forecast based on the weather

1. Write the ozone AQI from the National Weather Service Model in the box below.
2. Look at tomorrow's predicted temperature. Using what you know about how weather affects air pollution, decide if this will make the AQI go up, go down, or stay the same. Circle the correct choice in the column for temperature.
3. Repeat step 2 for all the other weather factors.

Starting AQI (National Weather Service)	**The temperature will make the AQI…**	**The wind will make the AQI…**	**The precipitation will make the AQI…**	**The sky condition will make the AQI…**	**The humidity will make the AQI go…**
	Go up	Go up	Go up	Go up	Go up
	Stay the same	Stay the same	Stay the same	Stay the same	Stay the same
	Go down	Go down	Go down	Go down	Go down

4. Based on the weather forecast, decide how the AQI will change. Will it go up or down? Will it change a lot or just a little?

   I predict that the AQI for ozone tomorrow will be: ____________________

   The color for this AQI is: ____________________

Part 4: Adjusting the AQI forecast for pollution blowing into the area (optional)

1. Look up the wind speed and direction by going to windfinder.com and zooming in on the area where the school is located
2. What direction is the wind blowing (ex. from east to west)? ____________________
3. Look up the current AQI for ozone by going to airnow.gov and typing in your city, state or zip code. When the new page comes up, click the map where it says "Current Air Quality."
4. When the map comes up, use the "Monitors" menu on the left to change the pollutant to ozone. Then zoom in on the area that the wind is coming from.
5. What is the AQI in that area? ____________________
6. If the AQI is very high, then pollution from the area may increase your AQI prediction. Go to the space above and adjust your prediction based on this information.

Activity 10 (Evaluate): Creating an Air Quality Report

Activity summary: To demonstrate what they've learned in this module, students create an air quality report including a forecast of future air quality conditions and recommendations for the public.

ACTIVITY DETAILS

Time: Two or more class periods

Objectives

- ✓ Students will show what they've learned from the module by creating an air quality report

Materials

- ✓ Students computers (highly recommended)
- ✓ Video recording devices (optional)

Handouts

- ✓ Project guidelines (adapted for your specific project)
- ✓ Grading rubric

Technology Tip

- ✓ If student computers are not available, you will need to print out relevant information for students to use to make their predictions.

Standards Connection

DCI: ESS3.C – Human Impacts on Earth Systems
DCI: ESS2.D – Weather & Climate
SEP: Developing & Using Models; Obtaining, Evaluating, and Communicating Information
CCC: Patterns; Systems & System Models

Warmup: Go to the Clean Air Partners website to show students the current AQI: https://www.cleanairpartners.net/current-and-forecasted-air-quality. Click on "Current" then choose the monitor closest to the school. Click on it to see the ozone AQI, and have students answer these questions:

- How close was our prediction to the actual AQI?
- Based on the time of day, do you expect the AQI to go up or down later today? Why?

If students' predictions are very close to the actual AQI, be sure to celebrate their success as meteorologists.

1. **Frame the activity:** Remind students that their goals from the beginning of this unit were:
   - To be able to explain the Code Red Day that happened in Washington, DC in 2018
   - To be able to predict other bad air quality days to help keep people safe

   To show that they've met these goals, they are going to use what they've learned about air pollution and weather to create a weather forecast that is focused on air quality.

Important Note about this Activity

There are a variety of options for how to have students create and share their weather reports. For example, you may choose to have students work in groups, and have them present their work like a television weather forecast. You can also have students create posters of their forecasts. You may have students create a report based on the prediction they made in the last activity, or you can have them use new data that they gather on their own. Choose whichever methods work best for you and your students, or give students options to show what they know in their preferred way.

TEACHER NOTES

Teacher Tip

- ✓ If you expect this project to take multiple days to complete, consider when you want students to make their predictions for. In other words, if the project will take 3 class days, consider having students make their predictions for the day the project will end (or the day after) instead of the first day after you start the project. Many weather websites have 7-day forecasts, and the NWS air quality forecast goes 36-hours ahead.

Modification

- ✓ If you have concerns about students all doing the same prediction for the same day, you can have them choose different days, or different locations. The AirNow website provides air quality data and predictions for the entire United States.

2. **Introduce the project.** Pass out the project guidelines for students and go over the requirements for the project. Answer any questions that students have about what the expectations are. Be sure to go over the timeline for the project as well, and what resources students will have available to them. You may also choose to share the project rubric with students in advance, or at some point during their work time.

3. **During the project.** Support students by suggesting resources, reminding them when they learned certain pieces of information, or being a thought-partner as they figure out how to present their information. Keep in mind that their goal in this project is to synthesize what they've learned and present it in an authentic way. Support them in their efforts to do this work, but do not do the work for them.

4. **Student presentations (optional).** If students are presenting their work, either as an oral report or presenting posters, provide time for them to practice their presentations and get feedback from you or from their peers using a peer feedback rubric like this free one from Teachers Pay Teachers: https://www.teacherspayteachers.com/Product/Presentation-Partner-Peer-Review-Rubric-4409187. If you are short on time, consider letting students record their presentations using laptop cameras, phones, or other digital recording devices. This way students can present, but you don't need to use class time to watch all the presentations.

5. **Evaluation and feedback.** Modify the attached grading rubric to match the type(s) of reports students have created. Be sure to use the rubric to provide feedback to students on their projects.

Name ____

STUDENT HANDOUT

Final Project: Creating an Air Quality Report

Project Guidelines

For this project, you will be creating a weather report based upon what you have learned during this module. You will be working (individually/as a group) to complete this project. Your weather report will be in the form of a (written report/poster/presentation). Your report will require you to do some research on predicted weather and air quality conditions. You will also likely need to use your materials from throughout the module to help you.

Your weather report must include the following information:

- A description of the predicted weather conditions including the temperature, sky condition, wind, and any precipitation, along with brief explanations of what each of these means in your own words
- A prediction for the ozone AQI color for tomorrow, including a recommendation for whether people need to adjust their behavior or not based on the air quality
- An explanation the process you went through to make your prediction, including specifics about why you made adjustments to the AQI.
- An explanation of what ground-level ozone is, where it comes from, and why we care about it as a pollutant.
- A comparison of tomorrow's predicted AQI with the AQI from the same date during some year in the past (you can choose any year you like). Comparison must include a comment on whether the difference is in line with historical trends or not.

Your report does not need to include this information in this order. You can be creative about how your present your information, and you are encouraged to use visuals as a part of your report.

The audience for your report is a person who does not know much about weather or air quality, so make sure to explain any technical terms you use, such as AQI.

You have ____________________ days to complete the project.

Available resources:

Student Name____

Air Quality Report Project Rubric

Project area	Beginning	Needs Improvement	Proficient	Advanced
Description and explanation of predicted weather conditions	Several descriptions of required weather conditions are missing, and/or are inaccurate. Explanations are missing or have significant inaccuracies.	Descriptions of most required weather conditions are included and are mostly accurate. Explanations have minor inaccuracies.	Descriptions of all required weather conditions are included and accurate. Explanations are accurate but not thorough.	Descriptions of all required weather conditions are included and accurate. Explanations are accurate and thorough.
Ozone AQI prediction	Ozone AQI prediction is unreasonable, and color does not math number. Recommendation does not match color rating or number, or is missing.	Ozone AQI prediction is somewhat unreasonable or color does not match number. Recommendation matches color rating or number.	Ozone AQI prediction is reasonable, and color matches number. Recommendation matches color rating, and uses generic language.	Ozone AQI prediction is reasonable, and color matches number. Recommendation matches color rating, and includes original suggestions.
Ozone AQI prediction process	Ozone AQI prediction process is explained incorrectly and/or information may be incorrect. Adjustments likely do not align with accepted scientific reasoning.	Ozone AQI prediction process is explained in very general terms, without specific steps described. Information may be missing. Adjustments may not align with accepted scientific reasoning.	Ozone AQI prediction process explains the steps for adjusting the AQI based on weather conditions, although steps may be lumped together or information may be missing. Adjustments align with accepted scientific reasoning.	Ozone AQI prediction process thoroughly explains each step for adjusting the AQI based on weather conditions, including adjustments for each weather condition. Adjustments align with accepted scientific reasoning.
Explanation of Ground-level ozone	Explanation of ground-level ozone is incomplete, and contains significant inaccuracies.	Explanation of ground-level ozone is missing some required aspects, or contains some inaccuracies.	Explanation of ground-level ozone is complete and accurate, with all required aspects addressed.	Explanation of ground-level ozone is thorough and detailed, with all required aspects addressed accurately
Comparison of predicted AQI with historical AQI	Historical AQI is incorrect.	Historical AQI is correct, but comment about fitting in with historical trend is inaccurate or illogical.	(see proficient)	Historical AQI is correct, and comment about fitting in with historical trend is accurate and logical.

Presentation quality	Presentation is generally unprofessional (ex. mostly ad lib) and strays from the topic. Presenter does not use scientific terms, and may stray from established time limits.	Presentation is led in a slightly unprofessional manner and may stray of topic or presenter gets easily distracted. Presenter occasionally uses scientific terms incorrectly and may stray from established time limits.	Presentation is mostly led in a "professional" manner and generally stays on topic. Presenter uses some scientific terms appropriately, and stays close to established time limits.	Presentation is led in a "professional" manner and stays on topic. Presenter uses scientific terms appropriately and stays within established time limits.
Craftsmanship	Poster/report has significant errors in grammar, spelling and/or formatting that make it difficult to understand. The product uses scientific terms incorrectly or not at all, and may have a sloppy look to it.	Poster/report has a few errors in grammar, spelling, and/or formatting. The product occasionally uses scientific terms incorrectly, and may a somewhat sloppy look to it.	Poster/report is well-made with attention to details such as grammar, spelling, and formatting, although there may be minor errors. The product uses some scientific terms appropriately.	Poster/report is well-made with attention to details such as grammar, spelling, and formatting. The product uses scientific terms appropriately and looks appealing.

Doing Our Part

- Plant an ozone garden at your school to identify whether ozone reaches harmful levels in your community. Specific species of plants are particularly sensitive to ozone and can indicate whether your community has an ozone problem. Learn more here: https://www.earthsciweek.org/classroom-activities/plant-ozone-monitoring-garden

- Look up the AQI using a computer or install an air quality app on your phone or your parents' phone. Use the AQI so you know when and how to avoid air pollution, especially on bad days.

- Be prepared for bad air quality situations, especially if you have asthma or other respiratory difficulties. For example, take your inhaler with you when the AQI is bad, and think about how you can get home from school if the air quality is bad.

- Avoid places where you know the air quality is likely to be bad, such as near roadways with lots of traffic (especially big trucks) or near power, cement, and chemical plants that are in your neighborhood. When walking to school, choose a route that stays away from busy streets.

- If you sometimes have difficulty breathing, talk to your parent(s) or doctor so they can make sure you get the help you need.

About this section

This section in included in every module either as a list or as part of an activity. It describes actions students can take to mitigate the effects of air pollution in their lives, and to help prevent air pollution from getting into the atmosphere. Many of these suggestions are the same from module to module, but there are variations depending on the focus of the module.

While the actions from this section are not explicitly built into the curriculum, they can be used in various ways to motivate students and provide them opportunities to take action to make a difference in their community. For more information, see the "Doing Our Part" section in "How to Use this Curriculum"

Air Quality Champion in Our Community

Name: Amelia Draper
Title: Meteorologist, StormTeam 4
Organization: NBC

How does your work relate to air quality?
As a television meteorologist, I am considered the station scientist. I am knowledgeable on most scientific topics, especially as they relate to climate, nature and natural disasters. As people plan their day, knowing the air quality is important and it is my job to tell them that information. Is it a day to stay indoors with poor air quality? Is the air quality impacting people with health issues like asthma and heart disease, or is the air clean and safe to breathe?

What is your workday like?
My time each day is spent forecasting the weather, building weather graphics, doing school visits or virtual visits, putting together a climate story and of course giving the forecast on NBC Washington, on social media as well as on WTOP radio. If there is severe weather I run weather crawls and alert the public to the current watches and warnings over social media and nbcwashington.com.

What motivates you to come to work every day?
I love my job! Knowing the forecast and effectively communicating the forecast are two different things. I am always looking to improve my communication of weather so non-meteorologists know what to expect when they step out their door. I also love the creative aspect of making new graphics.

What education and career path did you pursue to have the position that you have today?
I have a degree in meteorology from Penn State University. If you love math, science and communication, meteorology may be the career for you! I started working in a small television market more than 10 years ago, moved to a medium size television market then got a job in my hometown market of Washington, DC...my dream job!

Describe your workspace.
No lab for me! I rely heavily on computers and the internet to make my forecast and weather graphics. I use special websites to look at weather computer models, make weather graphics and create social media posts. After that, it is lights, camera, microphones and green screen!

What accomplishment are you most proud of?
I am most proud of making it back to my hometown market of Washington DC. I am also proud of a moment where I lost all of my typical weather graphics during a severe weather event and improvised ... viewers barely noticed!

Is there something important that you want to share that we haven't asked?
Dream big and ask for help! Get an internship, take some classes that push you out of your comfort zone and don't be afraid to try new things.

Glossary

anemometer – a scientific instrument for measuring wind speed

AQI (Air Quality Index) – a scale for reporting daily air quality. The AQI tells you how clean or polluted the air is in a given location, and what the associated health risks are. The AQI focuses on health effects you may experience within a few hours or days after breathing polluted air.

barometer – a scientific instrument for measuring air pressure

carbon monoxide (CO) - an odorless, colorless gas formed by the incomplete combustion of fuels. Can lead to poisoning because CO molecules will displace the oxygen in red blood cells.

Code Red Day – a day when the air quality index (AQI) is in the red zone (151-200) meaning that the air is unhealthy for everyone to breathe.

criteria pollutant – any one of the six air pollutants that are regulated by the EPA as required by the Clean Air Act. The criteria pollutants are carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide.

dew point - the atmospheric temperature below which water droplets begin to condense and dew can form

humidity – a measure of the amount of humidity in the atmosphere

hygrometer – a scientific instrument for measuring humidity

Inversion – a weather condition wherein a layer of cool air is trapped at the surface by a warmer air layer over it. Inversions can trap air pollution near the surface because the cool air will not rise into the warmer air. Also known as a temperature inversion.

nitrogen dioxide (NO_2) – a highly reactive gas that is a common air pollutant. Nitrogen dioxide primarily comes from burning fossil fuels in power plants, cars, trucks, and other vehicles.

ozone (O_3) - a natural and a man-made gas made of three oxygen atoms that occurs in the Earth's upper atmosphere (the stratosphere) and lower atmosphere (the troposphere). Depending on where it is in the atmosphere, ozone affects life on Earth in either good or bad ways.

particulate matter (abbreviation: PM) **-** a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Larger particles are called PM 10, smaller particles are called PM 2.5, based on their diameter in micrometers.

parts-per-billion (abbreviation ppb) – a unit of measure equal to 1 in 1 billion, or 0.0000001%. 1 ppb is also equivalent to 1 µg/liter.

parts-per-million (abbreviation ppm) – a unit of measure equal to 1 in 1 million, or 0.0001%. 1 ppm is also equivalent to 1 mg/liter.

sky condition – a measure of the percentage of the sky covered by opaque clouds.

smog – a haze caused by air pollution. Smog that is made of ground-level ozone is created when sunlight shines on particular kinds of air pollution and nitrogen oxides, especially from automobile exhaust. Smog can also refer to a haze caused by particulate matter pollution.

stratosphere - the layer of the earth's atmosphere above the troposphere, extending from about to about 4-8 miles above the Earth's surface to about 32 miles (50 km)

sulfur dioxide (SO_2) **–**a toxic gas that is often released when coal that contains sulfur is burned in a power plant

troposphere - the lowest region of the atmosphere, extending from the earth's surface to a height of about 4-8 miles (6–10 km), which is the lower boundary of the stratosphere.

MODULE 3

Air Pollution in the Community

Combustion, Particulate Matter, and Community Health

Module Overview

Burning fuel, the chemical process of combustion, has been a part of human civilization since we first started using fire for warmth and cooking. When the Industrial Revolution provided us electricity through widespread use of coal-burning power plants, combustion brought all new benefits, and many serious drawbacks. The advent of cars and trucks driven by internal combustion engines multiplied these effects. Combustion produces particulate matter, a form of air pollution that can have very serious repercussions for human health and the environment. In this module, students will take on the role of concerned community members who fear that their proximity to sources of particulate matter, both from combustion and other processes, is endangering their health. Acting as citizen scientists, they will learn about where particulate matter comes from, and how it affects human health. They will also measure particulate matter in their community. The module culminates in a simulated public meeting before a state committee where students will take on different roles to argue whether or not diesel trucks should be banned from traveling through residential neighborhoods.

Anchor phenomenon: Streams of particulate matter emitted from diesel vehicles.

Pacing

- 9 activities (2 optional) + summative assessment
- Approximately 10 class periods (plus 2 optional)

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When to Teach This Module

Finding the right place within a science scope and sequence to investigate air pollution with students can be tricky. Below you will find some information about the module that can help you decide where this it might fit into your own plans for student leaning:

- **Connection to Ecosystems**: Air pollution can have a tremendous effect on the health of ecoystems. The NGSS standards focus on how changes to a physical or biological component of an ecosystem can affect populations. In this module, the change in the ecoystem is particulate matter pollution, and the population affected is humans. Alignment to the standard would require additional examples of how other populations in the ecosystem is affected, but this module would fit well within a larger investigation of pollutants affecting ecosystems.

- **Connection to Human Health:** Air pollution from particulate matter pollution can have a significant impact human health. This module focuses specifically on how the health of a community is affected by particulate matter pollution. As such, it would fit well within a unit on the human respiratory and circulatory systems to add a real-world example of how the environment affects the health of human body systems.

- **Connection to Natural Resource Usage:** Air pollution is very much a story about human population and the consequences of how we use natural resources. While the module itself does not go into detail about kinds of natural resources, it would fit well as a part of a larger investigation of fossil fuels, and how our usage of those fuels affects human health.

Standards Overview

Middle School NGSS standards alignment

Performance Expectations

Focus PE:

MS-ESS3-3. Apply scientific principles to design a method for monitoring ~~and minimizing~~ a human impact on the environment.* [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).]

Background PEs:

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, ~~and on evaluating empirical evidence supporting arguments about changes to ecosystems~~.]

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Science & Engineering Practices

Focus SEP: Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s).

- Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

Background SEP: Analyzing Data
Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
- Distinguish between causal and correlational relationships in data.

Background SEP: Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.
- Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system.
- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.
- Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.

Disciplinary Core Ideas

Focus DCI: ESS3.C: Human Impacts on Earth Systems
Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3)

Background DCI: LS2.A: Interdependent Relationships in Ecosystems
Organisms, and populations of organisms, are dependent on their environmental interactions ~~both with other living things and~~ with nonliving factors. Growth of organisms and population increases are limited by access to resources.

Background DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (MS-LS2-4)

Background DCI: ETS1.B: Developing Possible Solutions
A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. Models of all kinds are important for testing solutions.

Crosscutting Concepts

Focus CCC: Cause and Effect: Mechanism and Prediction – Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

- Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.
- Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability

NGSS 5th Grade Standards alignment

Performance Expectations:

Focus SEP: **5-ESS3-1.** Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

Background SEP: **5-ESS2-1**. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. [Clarification Statement: Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere. The geosphere, hydrosphere, atmosphere, and biosphere are each a system.] [Assessment Boundary: Assessment is limited to the interactions of two systems at a time.]

Science & Engineering Practices

Engaging in argument from evidence
Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s).

- Construct and/or support an argument with evidence, data, and/or a model.
- Use data to evaluate claims about cause and effect.

Analyzing and interpreting data
Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations.
When possible and feasible, digital tools should be used.

- Represent data in tables and/or various graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships.
- Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.

Constructing explanations (for science) and designing solutions (for engineering)
Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.

- Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.

Disciplinary Core Ideas

ESS3.C: Human Impacts on Earth Systems
Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. (5-ESS3-1)

ETS1.B: Developing Possible Solutions
Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved.

Crosscutting Concepts

Cause and Effect: Mechanism and Explanation
Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain new contexts.

- Events that occur together with regularity might or might not be a cause and effect relationship.

Virginia Standards of Learning (SOLs) alignment

Science & Engineering Practices	
5.1 (c)	Interpreting, analyzing, and evaluating data. The student will… • represent and analyze data using tables and graphs • organize simple data sets to reveal patterns that suggest relationships • use data to evaluate and refine design solutions
5.1 (d)	Constructing and critiquing conclusions and explanations. The student will… • construct and/or support arguments with evidence, data, and/or a model • generate and compare multiple solutions to problems based on how well they meet the criteria and constraints
6.1 (c)	Interpreting, analyzing, and evaluating data. The student will… • organize data sets to reveal patterns that suggest relationships • construct, analyze, and interpret graphical displays of data • use data to evaluate and refine design solutions
6.1 (d)	Constructing and critiquing conclusions and explanations. The student will… • construct scientific explanations based on valid and reliable evidence obtained from sources (including the students' own investigations) • generate and compare multiple solutions to problems based on how well they meet the criteria and constraints
Content Standards	
6th Grade 6.9	The student will investigate and understand that humans impact the environment and individuals can influence public policy decisions related to energy and the environment. Key ideas include: c) major health and safety issues are associated with air and water quality; e) preventive measures can protect land-use and reduce environmental hazards; and f) there are cost/benefit tradeoffs in conservation policies.
Earth Science ES.11	The student will investigate and understand that the atmosphere is a complex, dynamic system and is subject to long-and short-term variations. Key ideas include c) natural events and human actions may stress atmospheric regulation mechanisms; and d) human actions, including economic and policy decisions, affect the atmosphere.

Common Core State Standards alignment

Literacy Standards	
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
RST.6-8.4	Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.
WHST.6-8.1	Write arguments focused on discipline-specific content.
WHST.6-8.1B	Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources.
SL.8.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.
SL.8.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.
Math Standards	
6.SP.B.5	Summarize numerical data sets in relation to their context

5E Module Flow

Activity 1 (Engage): The Trouble With Trucks
Timing: 45 minutes
Purpose: Introducing the anchor phenomenon
- ✓ Students will ask questions to clarify and define the phenomenon of point-source air pollution (truck exhaust)

Activity 2 (Explore): What Happens When Things Burn?
Timing: 45-60 minutes
Purpose: Connecting the physical phenomenon of exhaust from trucks with the scientific concepts of combustion and particulate matter
- ✓ Students will know that particulate matter (PM) comes from combustion
- ✓ Students will have an intuitive and a cognitive understanding of what PM 10 and PM 2.5 are.

Activity 3a (Explore): Measuring Particulate Matter Using Technology
Timing: 2-3 class periods
Purpose: Measuring particulate matter in and around the school to learn how to measure PM and to determine if there are any air quality issues in the local school community
- ✓ Students will be able to measure particulate matter using technology
- ✓ Students will be able to use their measurements to draw and support conclusions about how healthy the air is near the school

Activity 3b (Explore): Measuring Particulate Matter Using Engineering
Timing: 3-4 class periods
Purpose: Building particulate matter collectors to use around the school to develop engineering skills, learn how to measure PM, and to determine if there are any air quaity issues in the school community
- ✓ Students will be able to design, test, and deploy particulate matter collectors
- ✓ Students will be able to collect and analyze data to determine what areas of the school community have high levels of particulate matter in the air

Activity 4 (Explain): Particulate Matter and Human Health
Timing: 30-45 minutes
Purpose: Understanding how particulate matter affects human health at a physiological level
- ✓ Students will be able to identify the major health risks of particulate matter pollution
- ✓ Students will be able to compare and contrast the health effects of PM 2.5 and PM 10

Activity 5 (Elaborate): Particulate Matter in the Community
Timing: 45-60 minutes
Purpose: Understanding how particulate matter affects human health at the community level
- ✓ Students will analyze data in order to connect particulate matter pollution to health outcomes in a community
- ✓ Students will be able to distinguish between causation and correlation

Activity 6 (Elaborate): Air Toxics in the Community (optional)
Timing: 45 minutes
Purpose: Understanding hazardous air pollution and how it can affect communities
- ✓ Students will learn how scientists identify sources of toxic chemicals in the community
- ✓ Students will understand the difference between the criteria pollutants and toxic chemical pollutants

Activity 7 (Elaborate): Who is Polluting in My Neighborhood (optional)
Timing: 45-60 minutes
Purpose: Identifying potential sources of harmful air pollution in local neighborhoods
- ✓ Students will research air pollution sources in their communities and analyze their findings

Activity 8 (Elaborate): Not in My Backyard: Environmental Justice
Timing: 45-60 minutes
Purpose: Investigating environmental (in)justice using EPA's EJ Screen tool
- ✓ Students will understand the concept of environmental justice
- ✓ Students will investigate environmental justice in their community to see if certain groups of people are more frequently affected by air pollution

Activity 9 (Evaluate): Public Hearing on Banning Diesel Trucks in the Neighborhood
Timing: 2-3 class periods
Purpose: Understanding the public policy of air quality, and learning to advocate for air quality issues
- ✓ Students will explore and learn different perspectives on public policy related to air quality
- ✓ Students will make arguments based on evidence about whether or not diesel trucks should be banned in the community

Module Materials

Activity 1 (Engage): The Trouble With Trucks

- ❒ Handouts: none
- ❒ Materials needed: Computer & projector, sticky notes, sentence strips
- ❒ Optional materials: Air Quality Champions interview (see end of module)

Activity 2 (Explore): What Happens When Things Burn?

- ❒ Handouts: What Happens when Things Burn? notes sheet
- ❒ Materials needed: Two candles (large and small) and lighter/matches, glass jar that you can put over the small candle (or a metal can with the label removed), flour, flashlight, orange/match
- ❒ Optional materials: aluminum foil, ice, paper

Activity 3a (Explore): Measuring Particulate Matter Using Technology

- ❒ Handouts: Measuring PM in the Classroom, Measuring PM in the School Community
- ❒ Materials needed: AirBeams (approx. 1:4 students; see module for details), Android device with AirCasting app, clipboards, computer & projector
- ❒ Optional materials: Student computers

Activity 3b (Explore): Measuring Particulate Matter Using Engineering

- ❒ Handouts: Design a Partculate Matter Detector
- ❒ Materials needed: Graph paper, magnifying glass/dissecting scope, materials for building and testing the PM detectors (see module for details), scissors, additional blank paper
- ❒ Optional materials: none

Activity 4 (Explain): Particulate Matter and Human Health

- ❒ Handouts: The Health Effects of Particulate Matter
- ❒ Materials needed: Sentence strips, computer & projector
- ❒ Optional materials: Student computers

Activity 5 (Elaborate): Particulate Matter in the Community

- ❒ Handouts: Citizen Science: How Particulate Matter Pollution Affects a Community
- ❒ Materials needed: Graph paper
- ❒ Optional materials: Student computers

Activity 6 (Elaborate): Air Toxics in the Community (optional)

- ❒ Handouts: Air Toxics in the Community, Air Toxics and Criteria Pollutants
- ❒ Materials needed: Computer & projector, speakers
- ❒ Optional materials: n/a

Activity 7 (Elaborate): Who is Polluting in My Neighborhood? (optional)

- ❒ Handouts: Air Pollution Sources in My Community
- ❒ Materials needed: Computer & projector
- ❒ Optional materials: Student computers (highly recommended)

Activity 8 (Elaborate): Not In My Backyard: Environmental Justice

- ❒ Handouts: Environmental Justice Investigation Guide
- ❒ Materials needed: Computer & projector, internet connection
- ❒ Optional materials: Student computers (highly recommended)

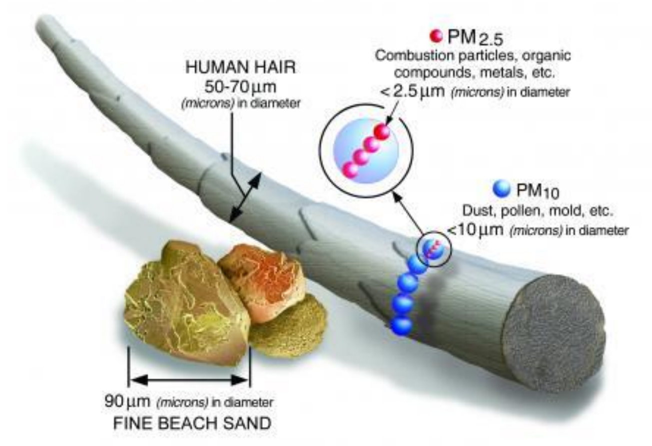
Activity 9 (Evaluate): Public Hearing on Banning Diesel Trucks in the Neighborhood

- ❒ Handouts: Role play stakeholder cards, Diesel truck ban role play scenario, Role play planning, hearing notes sheet, Cast Your Vote writing prompt
- ❒ Materials needed: Research materials (see module for details), presentation rubric (provided)
- ❒ Optional materials: Student computers, news article on California's diesel truck manufacturing phase-out

Teacher Background Information

Particulate Matter (PM) Basics

PM stands for particulate matter (also called particle pollution): the term for a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Others are so small they can only be detected using an electron microscope.



Particle pollution includes:

- **PM_{10}** : inhalable particles, with diameters that are generally 10 micrometers and smaller; and
- **$PM_{2.5}$** : fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller.
    - How small is 2.5 micrometers? Think about a single hair from your head. The average human hair is about 70 micrometers in diameter – making it 30 times larger than the largest fine particle.

These particles come in many sizes and shapes and can be made up of hundreds of different chemicals. Some are emitted directly from a source, such as construction sites, unpaved roads, fields, smokestacks or fires. Most particles form in the atmosphere as a result of complex reactions of chemicals such as sulfur dioxide and nitrogen oxides, which are pollutants emitted from power plants, industries and automobiles.

What are the Harmful Effects of PM?

Particulate matter contains microscopic solids or liquid droplets that are so small that they can be inhaled and cause serious health problems. Some particles less than 10 micrometers in diameter can get deep into your lungs and some may even get into your bloodstream. Of these, particles less than 2.5 micrometers in diameter, also known as fine particles or $PM_{2.5}$, pose the greatest risk to health.

Fine particles are also the main cause of reduced visibility (haze) in parts of the United States, including many of our treasured national parks and wilderness areas.

What is Being Done to Reduce Particle Pollution?

EPA regulates inhalable particles. Particles of sand and large dust, which are larger than 10 micrometers, are not regulated by EPA. EPA's national and regional rules to reduce emissions of pollutants that form PM will help state and local governments meet the Agency's national air quality standards.

How Can I Reduce My Exposure to PM?
You can use air quality alerts to protect yourself and others when PM reaches harmful levels:

AirNow: Every day the Air Quality Index (AQI) tells you how clean or polluted your outdoor air is, along with associated health effects that may be of concern. The AQI translates air quality data into numbers and colors that help people understand when to take action to protect their health.

- Go to About AirNow to learn how you can get AQI notifications.
- Also learn how the Air Quality Flag Program can help air agencies, schools, and other community organizations to notify their citizens of harmful conditions and adjust outdoor physical activities as needed.

Source: Particulate Matter (PM) Pollution, US EPA. https://www.epa.gov/pm-pollution/particulate-matter-pm-basics

Activity 1 (Engage): The Trouble With Trucks

ACTIVITY DETAILS

Time: 45 minutes

Objectives
- ✓ Students will ask questions to clarify and define the phenomenon of point-source air pollution (truck exhaust)

Materials
- ✓ Computer & projector
- ✓ Sticky notes
- ✓ Sentence strips (or other paper)

Handouts
- ✓ I See, I Think, I Wonder
- ✓ Air Quality Champion interview (optional) – see end of module

Teacher Tip
- ✓ If there are other vehicles that your students see regularly, consider showing them pictures of these as well (ex. buses) as long as they show the phenomenon.

Activity summary: In this investigation kickoff activity, students are introduced to the phenomenon of truck exhaust and – in the extreme case – coal rolling. They take a moment to consider what they already know about truck exhaust and come up with some questions about the topic before they begin exploring in the next activity.

Standards Connection

DCI: ESS3.C: Human Impacts on Earth Systems

Warmup: What kinds of trucks have you seen in your neighborhood?

- Students may identify garbage trucks, delivery trucks (ex. Amazon), dump trucks (if they are near a construction site), tractor trailers (ex. at grocery stores), tanker trucks (at gas stations)
- The purpose of this warmup is to provide information about what kinds of trucks students are familiar with, which will help with the rest of the investigation.

1. **Frame the activity:** Tell students that today they are beginning a new investigation. For this investigation, they are going to take on the role of citizens who are concerned about something they have seen in their community. In just a moment, they will see the same thing. Will they have the same concerns as the citizens? Let's find out.

2. **Introduce the Phenomenon: Diesel trucks:** Hand out the I See, I Think, I Wonder sheet for students. Tell them that in a moment you are going to show one or more videos of this event. Their job is to write down what they see in the top row of the sheets using as many details as possible.

   Show students one or more of the videos or pictures below that show diesel vehicles emitting large amounts of pollution. Choose the video(s) that you think students will recognize from their own experience:

   - Garbage truck (video, show just the first minute) https://www.youtube.com/watch?v=TMzfOLfE0eA
   - Dump truck (vide) https://www.youtube.com/watch?v=_VxpFDeBfIo
   - School bus (picture): http://electricschoolbuscampaign.org/wp-content/uploads/2018/04/Snapshot-5-4-7-2018-2-03-AM.png
   - "Rolling Coal" trucks modified to emit more pollution (video, show first minute) https://www.youtube.com/watch?v=sqyZ1N9hvNU

You may also choose to show them a picture of a truck like this one if it is a kind of truck you think they will be familiar with:

Afterwards, have students turn to a partner and share what they saw. Encourage them to add their partners' observations to their sheets. Then have partners share with the whole group. Use questioning techniques to help students focus on the exhaust from these vehicles, and to be as descriptive of it as possible. Ask students if they have ever seen trucks like this before, either in their community or somewhere else.

3. **I think:** In the "I Think" section of their sheets, have students write what they know about exhaust. They will have different amounts of background knowledge, but they at least know that it is smoke that comes from trucks. Then have them turn to a partner to share what they know. Afterwards, have students share something that their partner said about exhaust.

4. **I wonder:** On their own, have students write down what they wonder about truck exhaust in question form (ex. Where does the exhaust come from?). While they are writing, pass out sticky notes to small groups of students. When they are done writing, have each small group write down whatever questions they have about truck exhaust – one question on each sticky note. When they are ready, go around the class and have each group share one of their questions. You can rewrite these questions on the board or have students bring their sticky notes up to the front. After each question, ask if any other groups have the same question, and make a note of how many groups have that question. Tell students to put a check mark on their stickies whenever a question they have has been shared so that they only share new questions. Continue around the room until all groups have shared their questions.

TEACHER NOTES

Vocabulary

✓ Make sure that students are familiar with what you are referring to when you use the word "exhaust." They don't need to know what it is yet, but they should know you are referring to the smoke coming from the trucks.

Differentiation

✓ If students have difficulty creating questions, you can provide them with types of scientific questions to kickstart their thinking. For example: what is this made of? Where did this come from? Is this dangerous to humans? Is this bad for the environment? Is there an alternative to this?

TEACHER NOTES

Recommended reading

- ✓ For more on how delivery trucks affect pollution in cities, check out this short article from Scientific American: https://www.scientificamerican.com/article/delivery-vehicles-increasingly-choke-cities-with-pollution/

Recommended

- ✓ At some point during the module, have students read the interview with this module's Air Quality Champion to get them into the frame of mind of what they'll be investigating

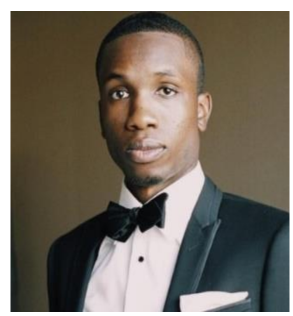
5. **Summarize questions.** With students' help, organize the questions into 2-4 groups of similar questions, and choose 2-4 overarching questions to summarize the category (the class may need to create questions that summarize each category). Ideally these will be questions that align closely with the goals of the module (ex. what is truck exhaust made of? Is truck exhaust harmful). Write these big questions on sentence strips (or other paper) and put them up on the wall. Tell students that you will use the questions to help guide their investigation.

6. **Trucks in the community:** Now that students have seen the phenomenon, return to idea that citizens in the community are concerned about these trucks. Ask students why people might be concerned (ex. there are young children around, there are people with asthma, etc.) In particular, ask if there are there people in the community that might be more concerned than others? Have the students ever experienced one of these trucks driving by? What was it like? Use this as an opportunity to help students' make a personal connection to the phenomenon and see it as something to be concerned about.

7. **Formative assessment.** You may use students' I See, I Think, I Wonder sheets as a formative assessment, since this activity is designed to kickoff the investigation. Alternatively, have students write a short answer about their experience with trucks like the ones in the pictures: ex. How do they feel about these trucks?

Air Quality Champion

Joshua Shodeinde is an air quality champion in our community. As an engineer at the Maryland Department of the Environment, Joshua helps develop clean air regulations. Learn more about Joseph, his work, and how he protects air quality at the end of the module.



Name ______________________________

STUDENT HANDOUT

I See, I Think, I Wonder

I See…
I Think…
I Wonder…

Activity 2 (Explore): What Happens When Things Burn?

ACTIVITY DETAILS

Time: 45-60 minutes

Objectives

- ✓ Students will know that particulate matter (PM) comes from combustion
- ✓ Students will have an intuitive and a cognitive understanding of what PM 10 and PM 2.5 are.

Materials

- ✓ Candle & lighter/ matches (you may want 2 candles, a bigger one for the first demonstration and a smaller one for the oxygen demonstration)
- ✓ Glass jar &/or metal can with label removed
- ✓ Word wall words
- ✓ Flour & flashlight
- ✓ Orange (or match)
- ✓ Glass jar, aluminum foil, ice, paper, match (optional)

Handouts

- ✓ Notes sheet: What happens when things burn?

Activity summary: In this activity, students begin to investigate combustion by observing a candle burn and looking at the soot it produces. They read about particulate matter and experience a variety of different demonstrations to understand the difference between PM10 and PM2.5

Standards Connection

SEP: Constructing Explanations

CCC: Cause and Effect

Warmup: Light the candle that you are going to use for the demonstration, and put it in a place where all students can see it. Have students describe what they see.

- Possible responses: It gives off light, there's something coming from the top, it's melting, it's burning, etc.

1. **Frame the activity:** Display the truck picture(s) from the phenomenon (Activity 1) while the candle is still burning. Tell students that the candle and the trucks have something very important in common. See if any students volunteer the idea that they both burn things. If not, ask them what they see coming from both the candle and the truck. Use questioning to help them focus on the smoke/exhaust, and the idea these both come from burning things. Both the truck (diesel fuel or gasoline) and the candle (wax) are burning things. Tell students that to understand what's happening in our truck pictures, we need to understand what happens when we burn things, so they are going to study burning today.

2. **Candle burning observations.** Pass out the notes sheet "What Happens When Things Burn?" and tell students to record observations of everything they are about to see on the left side of the graphic organizer (Candle observations) with one observation per block. Relight the candle if necessary, and hold the glass jar or can above it so that it collects some soot (you may need to hold it very close to the flame). After you have collected enough soot, remove the jar/can and show it to students. You can also wipe some of the soot onto a paper towel and pass it around so students can see it. Make sure that students also observe the wick (is it getting shorter?)

3. **Candle burning discussion.** Once students have finished making observations, have them share their observations with the class, and keep a record using the board or chart paper. Students can add each other's observations to their own sheets. Common observations: the wax melted, black stuff came from the flame and got stuck to the jar, the candle wick stayed the same.
   - If students have missed key observations (see below) use questioning to focus their attention on these events
   - Ask students if they know what the black stuff is that they observed. If anyone uses the word soot, then put this word up on the word wall, and have them add the word on their observation sheets wherever appropriate.

4. **Constructing explanations.** In pairs or small groups, have students look at their observations, and think about what could explain each of the things that they see. Use an example to get them started: I observed the wax melting because the fire was hot and the heat caused the wax to melt. Using the structure, "I observed <blank> because <explanation>" can help students with their thinking process. Have them write their explanations on the right side of the graphic organizer next to the observation. Afterwards, have students share their explanations and add them to the chart of the observations. After each explanation, see if there is consensus among the class about whether the explanation is true. Support students in reaching accurate conclusions, but if they are stuck on something, tell them that they will come back to it later when they have learned more.

Observations	Explanations
The wax melted	The fire was hot and the heat caused the wax to melt
The jar has black stuff (soot) on it	The candle is burning and it makes soot that got on the jar
The candle wick stays the same	The wick is not burning
There is smoke coming from the candle	When the candle burns, it makes a gas

TEACHER NOTES

Safety Note

✓ Whenever you plan to burn something in the classroom, be sure to have safety measures in place such as a fire extinguisher and fire blanket

Teacher Tip

✓ Make sure to try out the candle demonstration in advance. Some candles produce more soot than others, so you may want to try out a few different candles to find one that work well.

TEACHER NOTES

Teacher Tip

✓ If students bring up the wick as something needed for combustion, ask them if the wick disappeared when the candle was burning. You can use this as an opportunity to have them think about what the wick is for in a candle.

Teacher Note

✓ The particle turn and talk is designed to activate student background knowledge. The key takeaways will be addressed in the next section.

5. **Building vocabulary.** Tell students that scientists use special vocabulary to talk about burning. Put the words "**combustion**" and "**incomplete combustion**" on the word wall and ask if any students have heard the word combustion before. Explain that combustion is the scientific word for burning, and incomplete combustion is when something doesn't burn completely. Next put the words "**particulate matter (PM)**" on the word wall next to where soot is, and tell students that soot is a kind of particulate matter. It is called particulate matter because it is matter made up of small particles and it is abbreviated PM. Have students write definitions for these three terms on their notes sheets.

6. **Oxygen and combustion.** Light a small candle that you can put a glass jar over. Tell students that you are going to put the jar over the candle. Have them makes observations of what they see, then put the jar over the candle until it goes out.
   Like before, have students develop an explanation for this observation. Use questioning to help them reach the conclusion that combustion requires air/oxygen. Consider using the analogy of what would happen to a person if they were in a sealed room – eventually they would pass out from lack of oxygen.

7. **Summarizing combustion reaction.** Ask students what they think is needed for combustion. They should say air/oxygen (use this as an opportunity to clarify that combustion needs oxygen in particular, not just air). They may also say "a candle" or "wax." Help them to think back to the truck – does it run on wax? What word can we use to describe wood, gasoline, or wax – they are all fuels. Have students write oxygen and fuel in the "materials needed for combustion" box on the bottom of their notes sheet. Then ask them what they think is made from combustion. They should say soot and/or particulate matter. Have them write these in the "products of combustion" box. Ask if they know what the gases are in the smoke they saw coming from the candle. They may or may not know that carbon dioxide is the main gas. You can tell them that carbon dioxide and carbon monoxide are the main gases during incomplete combustion. Have them add these gases to the "products" box. Finally, tell students that hydrogen and oxygen are also products of combustion. They combine together: write H_2O on the board. See if students can identify this product (water) and have them write it on their sheets in the summary box.

8. **What burns?** Ask students what other things burn. Have them make a list in the space on their notes sheet. They will likely say things like wood, paper, matches, etc. Use prompts to help them think of other things: what burns in a stove (natural gas?) what burns in a grill? (propane or charcoal) what burns in a car? (gasoline). Have them add all these things to their notes sheet. Remind students that all combustion requires some kind of fuel.

9. **Turn & Talk: What is a particle?** Put the word "particle" up on the word wall, and have students turn to a partner to share what they think of as a particle. Use additional prompts as necessary (how big is a particle? What are particles made of? Can you give an example of a particle?). Afterwards, have students share out. Write down key takeaways for the group:
    - A particle is a very small part of something.
    - The word particle can mean a lot of different things – a particle of dust, an atom, or parts of an atom.

    After students share, point out that it's important when we use the word "particle" to be clear on what kind of particle we're talking about and how big they are, because there are many different kinds of particles.

10. **PM 10 and PM 2.5.** Tell students that scientists use the terms PM 2.5 and PM 10 to describe particles that are different sizes. Ask students what they think PM stands for (particulate matter) and which they think is bigger (PM 10). Have students look at the diagram on their notes sheet showing PM 10 and PM 2.5, and see what stands out to them. After they share, have them read the short paragraph below the diagram, and identify two similarities and two differences between PM 10 and PM 2.5.
    - Similarities: both are made of small particles, both are products of combustion, both are harmful to human health, both can be solid or liquid
    - Differences: PM 2.5 is smaller than PM 10, PM 2.5 can only be seen if there is a lot in once place, PM 2.5 can get into the human bloodstream, there are some differences in what PM 2.5 and PM 10 are made of (PM 10 includes dust, soot, pollen and various chemicals; PM 2.5 is mostly a chemical mix because it is usually smaller than dust and pollen)

11. **Demonstrating PM 10.** Prepare by taking a small amount of flour in your hand and turning off the lights. Have students prepare to observe, then toss the flour in the air and shine the flashlight on it. Ask students what they saw, and whether they think the flour is PM10 or PM2.5 (it is PM10). Students should be able to see the flour particles.

TEACHER NOTES

Teacher note

- ✓ Micron and micrometer are exactly the same unit of measurement. Micrometer is used in this module because it is the SI unit of measure and because students are likely more familiar with the prefix "micro-". Some diagrams (such as the one included on the student sheet) use the term micron, so you may need to clarify this for students.

Demonstration Safety

- ✓ Since breathing in PM2.5 and PM10 can be harmful, students should not breathe in the flour. Breathing in the scent from the match or the orange is not significant enough to cause harm.

Current Events

- ✓ Students may be interested in knowing how big coronavirus is compared to air pollution. One coronavirus is approximately 0.1 μm, which makes it much smaller than most PM 2.5.

TEACHER NOTES

Connection to Module 2

- ✓ Smog that causes a Code Red Day is the anchor phenomenon in Module 2. If you've taught this module with students, showing them how particulate matter and moisture can create smog may be a particularly interesting demonstration.

12. **Demonstrating PM 2.5.** Have students prepare to observe, then move to a corner of the room and either light a match and blow it out, or peel an orange. Have students raise their hands when they can smell the match or the orange. Ask them whether they think the scent particles from the match or the orange are PM10 or PM2.5 (they are PM2.5). Students should be able to detect that there are particles by the smell, but they are too small to see.

13. **Demonstrating Smog (optional).** Prepare to create the demo by putting a piece of aluminum foil over a glass jar to make a lid. Take the lid off, and put ice on it to cool it down. In the meantime, put a small amount of water in the jar and swirl it around to cover the inside. Light a small strip of paper with a match and drop the paper and the match into the jar. Quickly cover the jar with the foil lid. Allow students to observe. (What happens is the combustion products combine with the cooled water vapor to create a hazy smog: PM2.5).

14. **Visualizing Particulate Matter (optional).** Show students the New York Time's visualization and article on particulate matter here: https://www.nytimes.com/interactive/2019/12/02/climate/air-pollution-compare-ar-ul.html. Use the graph feature to compare the amount of PM2.5 in different cities around the US and the world.

15. **Formative Assessment.** Show students the pictures of the trucks from the original phenomenon and remind them of the questions they came up with during their first activity about the trucks and their exhaust. Have them use the information on their notes sheet to answer at least one of these questions using accurate scientific terminology (ex. "what is truck exhaust made of?". You may want to remind students that not all products of combustion are visible.
    - Both PM 10 and PM 2.5 are coming from the truck. While the soot (PM 10) is visible, other chemicals that make up PM 2.5 are also likely present even though we can't see them.

Name ______________________

STUDENT HANDOUT

What Happens When Things Burn?

Candle	
Observations	**Explanations**

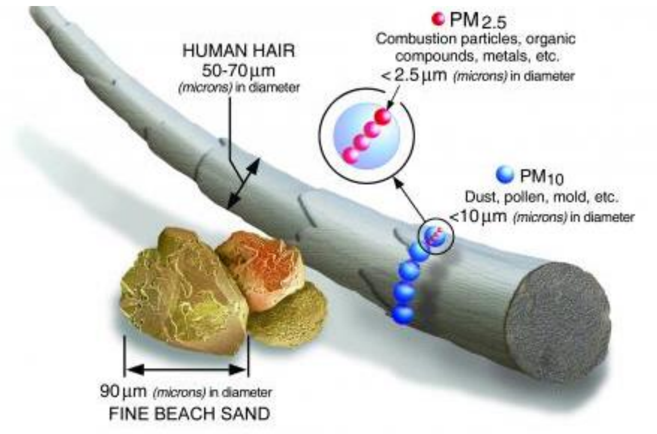
Combustion: ____________________

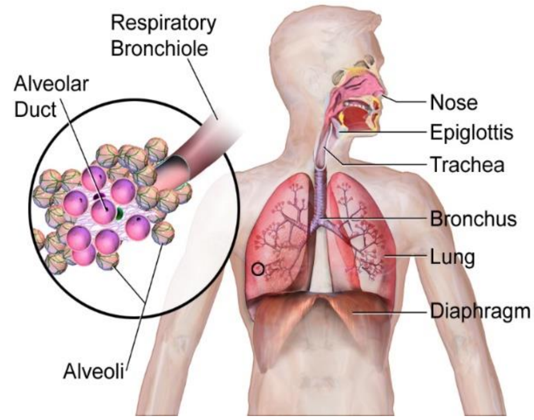
Incomplete combustion: ____________________

Particulate matter: ____________________

Materials needed for combustion	Products of incomplete combustion

What else is a fuel? What burns?





Reading

Particulate matter is one kind of air pollution that is a product of combustion. Large particulate matter or PM 10 is made of things like dust, pollen, soot and other chemicals. PM 10 is between 2.5 micrometers and 10 micrometers long. That is about one-fifth the width of a human hair. Small particulate matter or PM 2.5 is smaller than 2.5 micrometers. That means four particles of PM 2.5 are about the same length as one particle of PM 10. PM 2.5 is a mix of chemicals and metals that are very tiny. PM 2.5 is so small, you can only see it if there is a lot of it in one place. The funny symbol µ in the diagram above stands for "micro." One µm (micrometer) is 1/1000000th of a meter (one millionth) or 1/1000th of a millimeter. That's really small! Particulate matter can be a solid or a liquid, depending on the source of the pollution. All particulate matter is dangerous to human health when we breathe it into our lungs. PM2.5 is especially hazardous because it can go deep into the alveoli of our lungs and may even cross into our bloodstream and affect all parts of our bodies.

Name two similarities and two differences between PM10 and PM2.5

Similarities	Differences

Activity 3a (Explore): Measuring Particulate Matter Using Technology

Activities 3a & 3b

There are two different methods students may use to measure particulate matter. Each is described below. You may choose to do one or both activities, although the content in the two activities is similar.

- **Activity 3a** (high tech). Students use commercially available PM meters and android tablets to measure particulate matter pollution in and around the school in order to identify sources of PM and areas that may be unsafe due to air pollution. They gather and analyze data in order to support claims about how safe the air is around the school.
- **Activity 3b** (low tech). Students use the engineering design process to design a low-tech particulate matter detector. They test out their models, and then deploy them into the field where they can gather PM that is deposited. Next, they gather and analyze the data from their detectors in order to support claims about how safe the air is around the school.

Standards Connection

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
SEP: Analyzing Data

Activity summary: (see above)

Before starting this activity

- Read the information sheet: **AirBeams & AirCasting: How Does it Work?**
- Read the information sheet: Using the **AirBeam and AirCasting App** and familiarize yourself with how the AirBeam and AirCasting equipment works
- Setup stations for students to measure particulate matter indoors (ex. candle, incense, room deodorizer, etc.)
- Plan for any necessary chaperones for outdoor work on Day 2
- Add map of the school community (anywhere students may go for outdoor work) to the Day 2 data sheet: Measuring Particulate Matter in the School Community. If this isn't possible, you can have students write out their routes.

ACTIVITY DETAILS

Time: 2-3 class periods

Objectives

- ✓ Students will be able to measure particulate matter using technology
- ✓ Students will be able to use their measurements to draw and support conclusions about how healthy the air is near the school

Materials

- ✓ AirBeams (approx. 1:4 students) These may be purchased or borrowed in partnership with Clean Air Partners.
- ✓ Android device with AirCasting app
- ✓ Clipboards
- ✓ Computer & projector
- ✓ Student computers (optional)

Handouts

- ✓ Measuring PM in the Classroom
- ✓ Measuring PM in the School Community

Teacher Guides

- ✓ AirBeams & AirCasting: How does It Work?
- ✓ Using the AirBeams
- ✓ AirBeam Lesson Guide

TEACHER NOTES

Community Connection

✓ Take a moment to explain to students what a citizen scientist is, and how citizen scientists can contribute to the health of their communities

Modification Note

There are many different variations to how you might do this project, depending on your school grounds, availability of chaperones, etc. Consider what modifications, additions, or special preparations you may need to make based on your individual situation.

Warmup: What sources of particulate matter do you think there are near our school? (you can be broad with the definition of "nearby")

- Possible answers: schoolbuses (and other vehicles), construction sites (for dust), power/chemical plants that are upwind, wildfires, fields/trees that are producing pollen

1. **Frame the activity:** Tell students that now that they know the trucks in the pictures are emitting particulate matter, as citizen scientists it is their job to see if trucks or other sources of PM are making their own communities unsafe. For the next three days, they will measure and analyze the amount of particular matter in their community. Identifying and quantifying the sources of PM in a community is important so that community members can take action to protect their health and the environment.

   Due to the detailed directions required for using the AirBeams, a separate lesson guide follows. Below is an outline of the daily activities.

<u>Day 1 Outline</u>

1. Shows students how the AirBeam and AirCasting app works including a brief review of the internal workings of the device
2. Divide the class into groups and assign group roles.
3. Give each group an AirBeam and tablet to use and have them practice connecting the AirBeam and tablet using Bluetooth
4. Have students take measurements at various stations in the classroom
5. Using a Google Map of the school environment, plan routes where students can measure air quality at different locations during Day 2

TEACHER NOTES

Day 2 Outline

1. Refamiliarize students with the AirBeam equipment
2. Take students outside and lead them along their routes to collect data and make observations.
3. Return to class to analyze data and observations.

Day 3 Outline

1. Students complete analysis questions based on their data.
2. Students present their results to the class.
3. Students complete the "Conclusions" section of their data sheets including a Claim-Evidence-Reasoning argument.

AirBeam Lesson Guide

TEACHER GUIDE

Day 1

Note: Setup stations for measurements before class, but don't light any candles until students are ready to take measurements.

1. Tell students that for the new two days they are going to be collecting data with electronic devices called AirBeams that are paired with tablets (or smartphones).

2. Introduce the AirBeams and tablets to students by demonstrating how to turn on the devices and off, and how to connect them to the tablets (see "Using the AirBeam and AirCasting App")

3. Explain to students how the AirBeams work. Key points:
    - The AirBeams have a fan that pulls air into the device
    - There is an LED inside that shines a light on the air
    - The LED light is absorbed and scattered by the different sizes of PM
    - Sensors inside the AirBeam detect and measure the number of particles and their size by how much light is absorbed, and scattered
4. Divide the class into teams of four or more students depending on the number of instruments you have. Assigning roles to each member of the student team will help make sure all students are actively engaged. For Day 1, only roles 1, 2, and 4 are needed. For Day 2, all four roles will be needed. Each team member can be assigned one of the following roles:
    1) **AirBeam transporter**: makes sure the air beam is on and the air intake is clear and facing outwards. Stay within 10 feet of tablet.
    2) **Tablet carrier:** makes sure the tablet is connected, receiving and recording the data. Also takes photos of sources using tablet. Reads out the data for the group along the route.
    3) **Cartographer and timekeeper:** lead the team on agreed upon route. Identifies sources of pollution and makes notes on map
    4) **Data and note taker:** fill in the data table for # of sites agreed upon. Records observations.

5. Pass out AirBeams and tablets to each group. Make sure all group members know how to turn the AirBeam on and off, and how to pair it with the tablet. Remind students that the equipment is delicate and should be handled with care.

6. Pass out data collection sheets to students and review how they will collect data. The units of PM are $\mu g/m^3$. Explain to students how small a microgram is (one-millionth of a gram) and how big a cubic meter is.

7. Finish setting up PM source stations. Possible stations include a candle, an air freshener (spray), chalk dust, incense, etc.

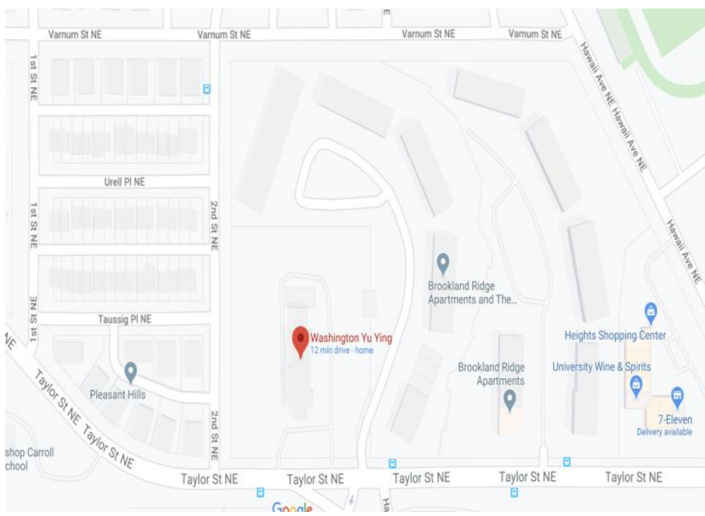
8. Have students rotate among the stations and collect data. As each team moves through the stations, they learn that commonly used items may release particulate matter. Have students switch roles at different stations so all students can practice using the AirBeam and using the AirCasting app on the tablet.

9. After the students have visited all the stations, have them return the AirBeams and tablets. Then have them review their data and answer the questions on their data sheets: What source emitted the most PM? Why do you think that is? What kind of PM was the most common? Why? Discuss

answers with students afterwards. You can also ask additional follow up questions such as: what happened when you moved closer or farther from a source?

10. To prepare for the outdoor portion of the investigation, project a Google Map of the school community and/or pass out printed maps to students. Based on their warmup answers, and the research they have just completed, have students identify possible sources of PM on their school grounds or in the community. Common sources include the bus and car drop-offs, vents from the school (from an incinerator or HVAC system), or a busy street nearby.

11. Finally, have students develop an AirCasting route based on their understanding of where and when particle pollution might be elevated. Also consider where the pollution is going to be the lowest as a comparison point. Make sure students consider the time of day – will there be cars or buses idling out front? If not, can someone collect data when there are buses? You may have different classes or perhaps teams of students test air quality at different times of the day or in specific parts of the school grounds or community. Some students may agree to arrive at school early one day to test when the buses arrive in the morning or stay late in the afternoon when parents are picking up students. Pass out the "Measuring Particulate Matter in the School Community" data sheets to students, and have them draw or write their route on the sheet, with numbers showing where they will collect individual data.



Example map for planning AirCasting route

Day 2

1. Organize students into their groups, and make sure that all students know their assigned roles. If students will be traveling with a chaperone, have the chaperone introduce themselves to the students.

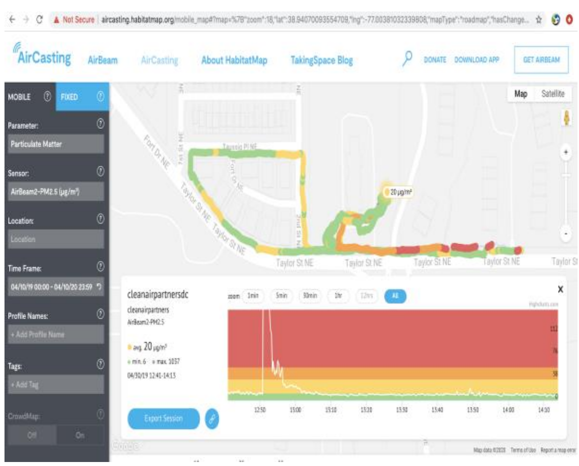
2. Make sure all student groups have their Measuring Particulate Matter in the School Community data sheets with their routes on them. Review what additional data students will collect while outdoors. They should use their various senses (sight, smell and hearing) and observe and note emission sources: ex: **mobile** sources such as moving cars, trucks, buses, a smoker AND **stationary** sources such as a vent, garage, nail salon. Note how close the source is to the sensor.

3. Hand out the AirBeams, tablets, and clipboards. Check to make sure all AirBeams and tablets are on and connected before going outside.

4. Take students outside to a central meeting location. If groups will be following different routes, make sure students and chaperones know what time they will meet back at the central location.

5. Students follow their agreed upon routes, collecting data as they go. When they have completed their routes, they return to the central meeting location.

6. When the student teams return to the classroom, have them upload the data to the AirCasting site (option crowdmap). If time permits, student teams should look at and analyze their data and be ready to share out their observation and results (otherwise this can wait until Day 3).



Sample data from the AirCasting website

7. Before the end of the class period, make sure to look up the PM2.5 levels for the area near the school. You can find this information by going to https://www.iqair.com/air-quality-map and using the map to find the nearest sensor. Be sure to record the PM2.5 level in μg/m³ (not the AQI).

Day 3

1. Have students work with their groups to complete the analysis questions on their data sheets. Lead a short sensemaking discussion afterwards to clarify student thinking, especially around the idea of where the PM in the school community is coming from.

2. Project students' data from the AirCasting website, and discuss the data to clarify any questions they have.

3. Have student groups present the data they collected and share what they learned. Groups should share:
   - Where they went
   - What they found (ex. sources)
   - What their data was
   - What they learned from their data collection and analysis
   - Anything they would do differently next time

4. Have students complete the "Conclusions" section on their data sheets, and lead a short discussion afterwards to review conclusions.

5. The final assessment for this activity is the Claim-Evidence-Reasoning argument. You may have students do this in class or as a homework assignment. Especially if students are new to writing CERs, it is worthwhile to provide feedback on their responses and have them revise their responses to ensure that their final CER is high quality.

   Sample CER:

   - Claim: The air near the bus drop-off is the least healthy for people to breathe.
   - Evidence: The level of PM 2.5 near the bus drop-off was 42.5. This was the highest of all our measurements.
   - Reasoning: PM 2.5 can get into your lungs and your bloodstream, which can cause many different health problems. The EPA chart shows that the amount of PM 2.5 near the bus drop off was in the "unhealthy for sensitive groups" range which was the worst rating for all of our tests.

Name ______________________________

STUDENT DATA SHEET

Measuring Particulate Matter in the Classroom

Connecting the AirBeam Sensor to the AirCasting App:

1. Turn on the AirBeam1. You'll know it's on when the red LED indicator begins blinking.
2. Turn on the android tablet or phone. Open the AirCasting app.
3. Press the menu button, then press Settings.
    - Press External devices, then select the AirBeam1 unique ID# (# will be on the AirBeam itself) from the list of paired devices. When prompted to connect, press Yes. You will then be redirected to the Sensors Dashboard.
4. In 5-20 seconds, measurements from the AirBeam will appear on the screen and the blinking red light on the AirBeam will switch to solid red. You're connected!

Data

Source (ex. candle)	PM 1.0 (μg/m³)	PM 2.5 (μg/m³)	PM 10 (μg/m³)

Which source had the highest level of any type of particulate matter? ______________

Why do you think this is? ____

____

What kind of particulate matter (PM 1.0. 2.5, or 10) had the greatest amount? __________

Why do you think this is? ____

____

Team Members: ______________________________________

STUDENT DATA SHEET

Measuring Particulate Matter in the School Community

My group's air testing route:

Insert Google map of the school community here.

Data

Location Number	PM 1.0 (µg/m^3)	PM 2.5 (µg/m^3)	PM 10 (µg/m^3)	Additional Observations Ex: school bus, vent, car, etc. how close is the sensor to the source?

Location Number	PM 1.0 (μg/m³)	PM 2.5 (μg/m³)	PM 10 (μg/m³)	Additional Observations Ex: school bus, vent, car, etc. how close is the sensor to the source?

Additional observations:

How windy is it? ____

Temperature: _______°F   Relative humidity: ________________ %

Analysis Questions:

1. Was the PM level on your route higher, lower, or close to what you were expecting?

   ____

2. Where were particle levels highest? ______________________________

   What is causing the PM level to be so high here? ______________________________

   ____

3. Where were the particle levels lowest? ______________________________

   Why do you think this was? ______________________________

   ____

4. Do you think the time of day or season affected your results? ____________________

   Why or why not? ______________________________

   ____

5. Where do you think most of the PM near the school is coming from? ____________________

   ____

<u>Conclusions: How healthy is the air near the school?</u>

When particulate matter levels get too high, they can be dangerous to our health. The chart below from the US Environmental Protection Agency (EPA) shows how healthy the air is based on the amount of PM2.5 and PM10. Keep in mind that these numbers are based on more than just one reading. They are based on the average amount of PM measured over a whole day.

	Good	Moderate	Unhealthy for Sensitive Groups	Unhealthy
PM 2.5	0 – 12.0 µg/m^3	12.1 – 35.4 µg/m^3	35.5 – 55.4 µg/m^3	55.5 -150.4 µg/m^3
PM 10	0 – 54.0 µg/m^3	55 – 154 µg/m^3	155 – 254 µg/m^3	255 – 354 µg/m^3

What is the PM2.5 level for the day you in your area (in µg/m^3) measured by the closest sensor?

____

You can find this information at: https://www.iqair.com/air-quality-map or by talking to your teacher

According to the chart, how healthy was the air? ____

How does the PM2.5 levels you measured compare to this? Are your readings higher or lower or a mix of the two?

____

____

Why do you think your readings might be different than the readings from the sensor? ____________

____

____

____

Write a Claim-Evidence-Reasoning argument about whether the air near your school is safe to breathe or not based on what you know about particulate matter. Make sure to use your data and the chart above to support your conclusion. You can choose to write about the area near the school in general, about specific areas near the school, or both.

Claim: Do you think the air is safe to breathe or not?

Evidence: What data do you have to support your claim?

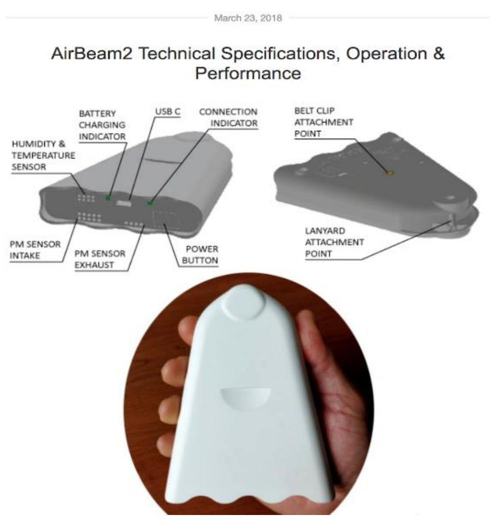
Reasoning: What do you know about particulate matter that makes your claim true based on the evidence?

AirBeams & Aircasting:
How does it work?

TEACHER GUIDE

The AirBeam is a palm-sized air quality monitor used to measure the amount of particulate matter in the air. Paired with an android device, and the AirCasting mobile app, citizen scientists, educators, students, and community leaders can take air quality measurements and contribute to a crowdsourced air quality map on the AirCasting website. Using the website, individuals can display and share air quality data.

The AirBeam uses a light scattering method to measure particulate matter (PM 1.0, 2.5 and 10). by drawing in air and measuring the concentration and size of particles using a light scattering method.



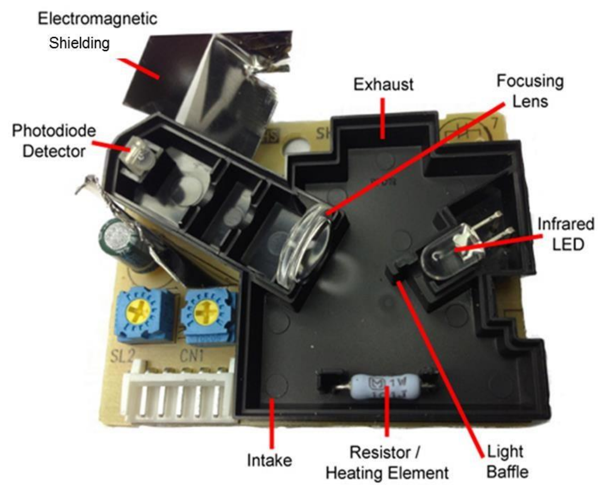


Image by Chris Nafas, modified by HabitatMap.

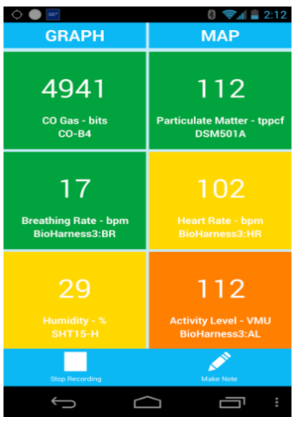
Once powered on, the AirBeam uses a small internal fan to create a partial vacuum which causes more air to flow into the AirBeams' "PM sensor intake". As the air is drawn through a sensing chamber, the infrared light from an LED bulb shines on the particles in the airstream. Some of this light is absorbed by the particles, and some is scattered. Two sensors inside the AirBeam: a particle-counting sensor and a light-scattering sensor, detect the number of particles and the amount of scattering. The information from the sensors is converted into a measurement that estimates the number of particles in the air (see below for more information on how estimates are calculated).

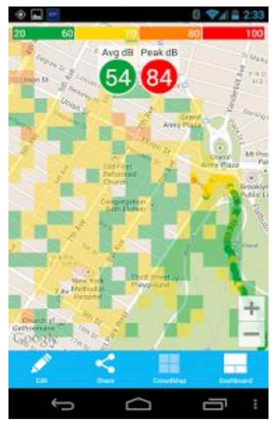
While the light scattering is related to the amount of PM in the air, the intensity of the light depends on a number of different factors.

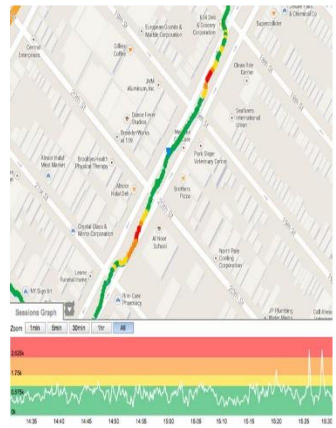
- Amount of particles
- Size of particles
- Wavelength of light
- Angle of light scattering
- Number of particles
- Color of particles

The AirBeam takes measurements of PM 1.0, 2.5 and 10 in µg/m³, as well as temperature and relative humidity. These measurements are taken once per second, and then communicated via Bluetooth to the AirCasting mobile app. The app maps and graphs the data in real time on your android smartphone or tablet. At the end of each AirCasting session, the collected data is sent to the AirCasting website, where the data is crowdsourced with data from other AirCasters to generate maps indicating where PM concentrations are highest and lowest.

An AirCasting session lets users capture real-world measurements, annotate the data and share it via the crowdmap on the AirCasting website. Using the AirCasting mobile app, AirCasters can record, map, and share 3 levels of PM concentration (1.0, 2.5, and 10), temperature, sound levels, and humidity.







* **Particulate Matter 1.0, 2.5 and 10 µg/m3:** Particles scatter light at an angle and intensity that is dependent on their size. When light strikes a particle, it is either diffracted, refracted, reflected, or absorbed. Smaller particles scatter light more intensely and at smaller angles than larger particles. Each particle size produces a unique scattering pattern. The intensity of light scattered is a function of its wavelength λ, scattering angle θ, particle size d_p, and relative index of refraction n between the medium and particle.

Photodetectors detect the intensity of scattered light. The energy of incident photons (elementary particle of light) on these devices cause electrons to be liberated. This produces an electrical signal (current) which is proportional to the intensity of detected light. This signal is converted into a measurement that estimates the number of **Particulate Matter 1.0, 2.5 and 10 µg/m3.**

Using the AirBeam & AirCasting App

Each AirBeam has a unique number that gets connected to the AirCasting App on the tablet to transmit the data. Once the AirBeam is connected to the tablet the data is transmitted every second and recording can take place. If the tablet is connected to WiFi the data will be visible on a map. If WiFi is not available, the data will be associated with a GPS location and will be placed on the map when uploaded to the AirCasting platform.

Connecting the AirBeam to the Android Tablet or Phone

Connecting the AirBeam Sensor to the AirCasting App:

1. Turn on the AirBeam1. You'll know it's on when the red LED indicator begins blinking.
2. Turn on the android tablet or phone. Open the AirCasting app.
3. Press the menu button, then press Settings.
    - Press External devices, then select the AirBeam1 unique ID# (# will be on the AirBeam itself) from the list of paired devices. When prompted to connect, press Yes. You will then be redirected to the Sensors Dashboard.
4. In 5-20 seconds, measurements from the AirBeam will appear on the screen and the blinking red light on the AirBeam will switch to solid red. You're connected!

Activity 3b (Explore): Measuring Particulate Matter Using Engineering

ACTIVITY DETAILS

Time: 3-4 class periods

Objectives

- ✓ Students will be able to design, test, and deploy particulate matter collectors
- ✓ Students will be able to collect and analyze data to determine what areas of the school community have high levels of particulate matter in the air

Materials

- ✓ Magnifying glass or dissecting scope
- ✓ Graph paper
- ✓ Materials for building the detector (see note below)
- ✓ Materials for testing the detector (ex. flour and pencil shavings)
- ✓ Scissors
- ✓ Additional paper for students to brainstorm and design

Handouts

- ✓ Design A Particulate Matter Detector

Activity summary: Students use the engineering design process to design a low-tech particulate matter detector. They test out their models, and then deploy them into the field where they can gather PM that is deposited. Next, they gather and analyze the data from their detectors in order to support claims about how safe the air is around the school.

Engineering Note

If students have not done any engineering in this class before, it is worth taking the time to teach them the engineering design process and doing a sample activity. Introductory information can be found at: https://www.teachengineering.org/k12engineering/designprocess. A good sample activity to do with students is the parachute design activity here: https://www.teachengineering.org/activities/view/design_a_parachute

Standards Connection

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
DCI: ETS1.B: Developing Possible Solutions
SEP: Designing Solutions, Analyzing Data

Warmup: What sources of particulate matter do you think there are near our school? (you can be broad with the definition of "nearby")

- Possible answers: schoolbuses (and other vehicles), construction sites (for dust), power/chemical plants that are upwind, wildfires, fields/trees that are producing pollen

1. **Frame the activity:** Tell students that now that they know the trucks in the pictures are emitting particulate matter, as citizen scientists it is their job to see if trucks or other sources of PM are making their own communities unhealthy. During the next few days, they will design, test, and deploy devices to measure the amount of particular matter in their school community. Measuring the amount of PM in the community is very important to know whether people's health might be harmed from this type of air pollution.

Community Connection

Take a moment to explain to students what a citizen scientist is, and how citizen scientists can contribute to the health of their communities.

2. **Introduce the Engineering Design Challenge:** Hand out the "Design a Particulate Matter Detector" sheet to students, and read the problem and goal together with them. Make sure all students understand the purpose of the challenge. Next, review the criteria for the detector (A successful device must…)
   - Collect visible particulate matter (PM 10)
   - Limit the amount of non-particulate matter collected (ex. hair and dirt)
   - Include a method for measuring or counting the amount of PM collected (ex. using a magnifying glass and a grid for sampling)
   - Be able to survive intact outside for at least 2 days on its own

   Next, review the constraints for this challenge (A successful device can only…)
   - Use materials provided by the teacher or ones you can get from home
   - Take no more than two periods to build prototypes, test, and create TWO identical final versions for use in monitoring

   Take any time as necessary to answer students' questions about the criteria and constraints.

3. **Review testing procedures.** Explain to students how their monitors will be tested before being used in the field. There are several options you can use based on available materials, but in general, they should involve dropping sample particulate matter (ex. chalk dust or flour) on the detector, along with larger debris (ex. pencil shavings). A successful test means the flour gets in, the shavings are kept out, and there is a way to measure how much flour is on the monitor.

4. **Review materials**: Discuss the list of available materials with students, and review any additional rules for what students may bring in (ex. can they buy materials or do they have to be things they can find around the house?)

5. **Brainstorming ideas.** Form students into pairs, and have them begin by brainstorming different ideas for their designs on their handouts. if you think students will have a difficult time getting started, do this brainstorming as a class first. A good way to get students started is by having them think about how they can get the PM to stick to the detector. Write down options on the board.

TEACHER NOTES

Teaching Tip

✓ When reviewing the criteria, pause and consider places where the detectors might be placed. Include places where PM might be high (ex: bus drop off, parking lot) and low (ex. playground, field). Use students' answers from the warmup to support this discussion.

Timing

✓ The time for this challenge is flexible. Adjust based on length of class periods and how long students take to build and test their prototypes. It will likely take at least 2 class periods for students to go from initial design to final products.

Engineering materials

✓ Common materials students may want to use for their detectors are: paper plates, cardboard boxes and tubes, tape (regular and double-sided), petroleum jelly, string, glue, graph paper (to measure PM), note cards, duct tape, coffee filters, popsicle sticks, and pipe cleaners.

TEACHER NOTES

Teaching Tip

- ✓ Make sure to have extra paper on hand for students to brainstorm or create designs.

Modification

- ✓ To help students minimize materials use, assign a value to each item (ex. double sided tape = $10 per foot) and give students a budget. They earn extra points on their design if they are under budget.

Documentation

- ✓ Documenting student progress through the engineering design process is a good way to show their learning progress. Take pictures of students, their designs, prototypes, and final products to help them reflect on their work later. This is especially helpful if students reuse materials from their prototypes in their final products.

6. **Creating designs:** Once students have a good set of ideas brainstormed, have them start designing their PM detectors on their sheets. Each part of their design must be labeled, and the design must address each aspect of the criteria. For example, make sure students have a way to sample the amount of PM without trying to count it all by using a grid. Check student designs and provide feedback. Try not to be judgmental – even if you think something won't work, let students try so they can learn on their own. Also make sure that students have written a way to measure the amount of PM in their monitor on their handouts. Suggested methods include putting a grid under their "sticky" material so they can count/measure the amount in a few grids as a sample. When a design looks good, allow groups to begin building prototypes.

7. **Building prototypes:** When a group has an approved design, they can take materials and start building. Be sure to control access to resources so one group doesn't take too much of one resource (see modification note on budgets for an option on how to do this).

8. **Testing prototypes:** As groups finish their prototypes, have them test using whatever protocols you have established. For example, shake flour through a sieve from 12 inches above the detector, and sprinkle pencil shavings from 12 inches above the detector. See if the prototype can keep the non-PM out and allow the PM in. Also check if students can count/measure the amount of PM in a quantitative way.

9. **Redesign and improvement:** As students make improvements to their designs and prototypes, support them by giving feedback and keeping them aware of time constraints. Try to avoid making suggestions, and instead ask questions to drive their design thinking. For example, "What materials could you use to help keep dirt out of the detector?" or "How can you use a grid to allow you to sample the amount of PM in the detector instead of counting it all?" or "What can you use to keep your detector from blowing away?"

10. **Build final designs**: Once students have reached their final products, have them create two identical versions. This will allow them to compare results from two different locations in a valid way.

11. **Choose locations for monitoring:** As a class, choose locations around the school where the monitors will be placed. Try to avoid having the same pairs in the same locations (ex. If group A has their monitors in locations 1 and 2, then group B might have their monitors in locations 1 and 3). Have students record their locations on their handouts.

12. **Deploy monitors**: Put monitors out in their designated locations, and attach signs nearby indicating what they are and not to leave them alone. If you are concerned that monitors may be damaged by students, weather, etc., consider ways to avoid this, for example by putting them on a roof or on a high ledge. Leave monitors for at least one day. Check on them after 24 hours to see how they are doing. If results seem viable, bring them in; if not, try waiting an additional day or more. You can continue with the next activity in the meantime.

13. **Data collection.** Once monitors are ready to be analyzed, bring them back to the classroom and have students measure the amount of PM in each monitor using the method they have determined. While these measurements may not be completely accurate, they should be able to determine which of their two locations are better or worse in terms of PM.

14. **Data share:** Share data across groups to determine an order of best to worst location (see note on comparative data analysis). It may help to have students write their data on note cards so these can be sorted by location. Have students record the class data on their handouts.

15. **Analysis questions:** Have students answer the analysis questions on their handout based on the class data. Lead a short class discussion to clarify student thinking, with a special emphasis on where they think the PM in their school community is coming from.

16. **Formative assessment (Conclusion):** Have students answer the Claim-Evidence-Reasoning prompt on the last page of their handout. An example response might be:
    - **Claim**: The air near the bus drop-off is the least healthy for people to breathe, and the air at the playground is the most healthy.
    - **Evidence**: Monitors at the bus drop-off collected the most particulate matter compared to the other monitors around the school. Monitors at the playground collected the least.
    - **Reasoning**: If you breathe in high amounts of PM 10, it can get into your lungs and make breathing difficult. Because we collected the most PM 10 at the bus drop-off, that means the air there is the least healthy. We collected the least PM 10 at the playground, making the air there the most healthy.

17. **Reflection:** Have students reflect on the project, either through writing or discussion. If you took pictures during the project, share them with students. Some useful questions to ask are:
    - What did you like most/least about this project?
    - Was this project fun? Why or why not?
    - Did you ever get frustrated by your design? If so, how did you overcome your frustration?

Team Members______________________________

TEACHER NOTES

Comparative data analysis

✓ Because students will have different designs, comparing data from one group to the next would be invalid. Instead, use comparisons between different groups to establish which sites had higher and lower amounts of PM. For example, if Group A had more PM at site 1 than site 2, and Group B had more PM at site 3 than site 1, then it can be inferred that site 3 likely has the most amount of PM of the three locations.

STUDENT GUIDE

Design a Particulate Matter Detector

Engineering Design Challenge

Problem: Particulate matter in the air can be damaging to human health if it is breathed in. PM 10 can irritate the lungs and cause respiratory problems. PM 2.5 can enter the bloodstream and cause health problems throughout the body. Because particulate matter is hard to see, a device is necessary to detect and measure it.

Goal: Work with a partner to design and deploy a detector for collecting and measuring the amount of particulate matter in the school community.

Criteria: A successful device must…

1. Collect visible particulate matter (PM 10)
2. Limit the amount of non-particulate matter collected (ex. hair and dirt)
3. Include a method for measuring or counting the amount of PM collected (ex. using a magnifying glass and a grid for sampling)
4. Be able to survive intact for at least 2 days outside on its own

Constraints: A successful device can only…

5. Be made of materials provided by the teacher or ones you can get from home
6. Take no more than two periods to build prototypes, test, and create TWO identical final versions for use in monitoring

Materials:

- Cardboard boxes and tubes
- Paper plates
- String
- Tape (regular and double-sided)
- Glue
- Graph paper
- Note cards
- Duct tape
- Coffee filters
- Popsicle sticks
- Pipe cleaners

Brainstorm ideas
Designs – don’t forget to label all parts of your design!

I will measure the amount of PM in my monitor by…
Data collection: Location 1: Location 2:
Data: Amount of particulate matter collected at Location 1: Amount of particulate matter collected at Location 2:
Class Data: Location with least PM: Location with most PM:

Analysis Questions

1. Was the PM level on your detectors higher, lower, or close to what you were expecting?

   ____

2. Where were particle levels highest? ______________________

   Why do you think this was? ______________________________

   ____

3. Where were the particle levels lowest? ______________________

   Why do you think this was? ______________________________

   ____

4. Where do you think most of the PM near the school is coming from? __________

   ____

Conclusion

Write a Claim-Evidence-Reasoning argument about what areas around your school have the cleanest or most polluted air based on what you know about particulate matter. Make sure to use your class data to support your conclusion.

Claim: What areas have the cleanest and the most polluted air?

Evidence: What data do you have to support your claim?

Reasoning: What do you know about particulate matter that makes your claim true based on the evidence?

____

____

____

____

____

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____

Activity 4 (Explain): Particulate Matter and Human Health

ACTIVITY DETAILS

Time: 30-45 minutes

Objectives

- ✓ Students will be able to identify the major health risks of particulate matter pollution
- ✓ Students will be able to compare and contrast the health effects of PM 2.5 and PM 10

Materials

- ✓ Sentence strips
- ✓ Student computers (optional)
- ✓ Computer & projector

Handouts

- ✓ The Health Effects of Particulate Matter

Teacher Tip

- ✓ If you have already done Module 1 with students, you can choose to skip this activity, or take a moment to refresh students' memories by replaying the Lung Attack Simulation.

Activity summary: In this activity, students learn about the major health effects of particulate matter pollution by engaging with a simulation and watching a video. They also determine what things they believed about combustion pollution are true and which are false.

<u>Standards Connection</u>
DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
CCC: Cause and Effect

Warmup: Think back to the trucks we saw at the beginning of our investigation. How do you think the air pollution that comes from those trucks can affect our bodies?

- Possible answers: it hurts our lungs, it makes us sick, it makes us cough, it makes us sneeze.

1. **Frame the Activity.** Ask students if any of them live near a busy road, or if they see a lot of trucks in their community. Have they ever wondered if the exhaust coming out of the trucks is harmful? Remind them of the videos they watched at the beginning of the investigation. What do they think it would be like if they were standing by the road when one of the trucks drove by? Tell students that in this activity, they'll learn more about how particulate matter affects the human body.

2. **Fact or Fiction:** Take students' answers from the warmup, and put them on sentence strips (or write them on the board). Tell students that they are going to decide which are facts and which are fiction. Ask them if they have any other ideas about what might be true or not about particulate matter.

   If students have not mentioned these, then add them to the list:
   - air pollution can get into our blood
   - air pollution can hurt your brain

   If none of the students' statements are false, considering adding something fictional like: air pollution can cause your skin to change color.

3. **Lung Attack:** Hand out the Health Effects of Particulate Matter notes sheet. Tell students that they are going to be watching a simulation that shows some of the health effects of particulate matter on the human body. As they watch, they should answer the questions on their handout.

If students are going to use computers to interact with the simulation on their own, then pass out computers and direct students to the Lung Attack Simulation:
http://web1.pima.gov/deq/lungattack/lungplay.htm

If students will be watching the simulation together, project it so that all students can see and lead students through the simulations for PM2.5 and PM10.

After students have seen both the PM2.5 and PM10 portions of the simulation, take a few minutes to discuss their answers to the questions to clarify any misconceptions. They may have some gaps in the PM2.5 portion of the notes sheet, which they will be able to fill in during the next video.

4. **UNICEF video (optional):** This video focuses on PM 2.5, so have students add additional notes from this video on that side of their handout. **Note:** some of the information in this video can be disturbing, so you may choose not to show it to students. If you do show the video, it is **highly recommended** that you stop it at 1:15 or 1:59. You may consider discussing students' reaction to the video after they have watched. The link to the video is here: https://www.youtube.com/watch?v=QcS3ovdsgNI

5. **Compare and contrast:** Have students answer the compare and contrast questions at the bottom of their notes sheet. Review their responses to clarify their understanding.
    - Similarities in health effects: both can affect the lungs causing difficulty breathing, coughing, and lung irritation
    - Differences: PM10 mainly affects the lungs and affects breathing. PM2.5 can enter the bloodstream, and cause effects throughout the body, including damage to the brain

6. **Return to Fact or Fiction:** Go back to students' statements from the beginning of the activity about the effects of air pollution from the trucks. Have them sort the statements by fact (true) or fiction (false). If there are some statements they don't yet know the answer to, you can leave them in undecided of give students a chance to look up the answers.

7. **Question check-in:** Take a moment to look back at the questions students generated during Activity 1. If there are any questions that you have answered, make sure to recognize this, and have students articulate a clear answer to the question. You may choose to use this in place of their formative assessment if appropriate.

8. **Formative assessment:** Have students answer the prompt: "Do you think the government should limit where combustion-powered trucks can go based upon what you learned today? Use evidence from your notes sheet to support your answer.

ACTIVITY DETAILS

Technology Note

✓ Lung Attack uses Flash player, which may need permission to run on your computer. Keep an eye out for a pop-up asking for permission for Flash player to run.

Alternative Media

✓ For an alternative that is more comprehensive (and comical), show students the US National Library of Medicine's Video "Something in the Air: Particulate Matter and Your Health" found at: https://www.youtube.com/watch?v=zrHmD94F95A The video is long (20 minutes) but consider showing only a portion of it.

Teacher Tip

✓ This formative assessment is a teaser for the public health debate that will come at the end of the module

STUDENT HANDOUT

Name____

The Health Effects of Particulate Matter

Particulate Matter 2.5	Particulate Matter 10
What is it? Examples: Where does it come from? What happens when it gets in your lungs? How does your body react? What part(s) of your body does PM2.5 affect?	What is it? Examples: Where does it come from? What happens when it gets in your lungs? How does your body react? What part(s) of your body does PM10 affect?

How are the health effects of PM2.5 and PM10 similar? ____

____

How are the health effects different? ____

____

____

Activity 5 (Elaborate): Particulate Matter in the Community

Activity summary: In this activity, students analyze data based on real world studies of the health effects of living near a roadway. Through their data analysis, they are able to make connections between particulate matter and the health of an entire community.

Standards Connection
DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
SEP: Analyzing Data, Engaging in Argument from Evidence
CCC: Cause and Effect

Warmup: Where does particulate matter come from?

- Answer: power plants, fires, chemical plants, fields, vehicles, etc.
- This is a review of content they've learned previously to focus their attention on sources of PM for this lesson.

1. **Frame the activity:** Remind students that at the beginning of the last activity you asked if anyone lived in a neighborhood that had a busy road or a lot of trucks. Have them think about a community like that, even if they don't live in one. Imagine you live in a place where there is a lot of particle pollution. Ask students what they would do about it. They may suggest things like wearing a mask or staying indoors. Tell students that one thing people can do is act as citizen scientists, just like they did in Activity 3. Citizen scientists help study the problems in their community and come up with solutions to solve them. In this activity, they will study how particulate matter pollution can affect a whole community.

Community Health is Serious Business

During this activity students will investigate some serious topics (ex. cardiovascular disease) which they may have personal experience with. Be sure to address this carefully and with the sensitivity and seriousness that topics like this deserve. While the data they are examining is fictionalized, it is based on actual results from a variety of studies. See the accompanying documents for the sources used.

2. **Monitors vs. sensors:** Remind students of the particulate matter devices they used or built in Activity 3. Tell students that scientists use PM monitors that are permanently installed in different places to measure PM all the time. You can show them a picture like the one below. As citizen scientists, we can look up the data from these monitors if we want to know how high the air pollution is.

ACTIVITY DETAILS

Time: 1-2 class periods

Objectives

- ✓ Students will analyze data in order to connect particulate matter pollution to health outcomes in a community
- ✓ Students will be able to distinguish between causation and correlation

Materials

- ✓ Computer & projector
- ✓ Student computers (optional for graphing)

Handouts

- ✓ Citizen Science: How Particulate Matter Pollution Affects a Community
- ✓ Graph paper

Teacher Tip

- ✓ In upcoming activities, students will be reminded of these monitors as a way to advocate for themselves (by having monitors installed)

TEACHER NOTES

This data from these monitors is more accurate than what we collected because the monitors are more sensitive and they are measuring PM all the time. You may also choose to show students this short video about the difference between personal sensors and EPA monitors: https://youtu.be/whP6CDWJ-fM. For their citizen science research, they'll be analyzing data that comes from monitors like this.

A particulate matter monitor
in Kansas City, MO

3. **Introduce the investigation:** Tell students that for their citizen science research, they are going to study how air pollution affects not just one person, but a whole community. Pass out the "Citizen Science: How Particulate Matter Pollution Affects A Community" handout. Have students look at the blank data table at the top. Ask students what things they see on the data table. Students should be able to pick out things like: major roadways, miles, cardiovascular disease, and asthma.

4. **Community health variables:** Ask students if they can identify the health outcomes that they will be looking at. They should recognize that the health outcomes are on the left-hand side of the chart. Review what each of these things means so students understand what data they will be looking at and what a "health outcome" is. Have them write their own explanations in the blanks on their handout.
    - **Cardiovascular disease**: heart/circulatory system disease (ex. high blood pressure, blocked arteries, etc.)
    - **Lung function**: volume of air you breathe in and out
    - **Emergency room visits due to asthma**: difficulty breathing, wheezing, coughing that requires an ER visit
    - **COPD (bronchitis)**: difficulty breathing, coughing, wheezing that is persistent

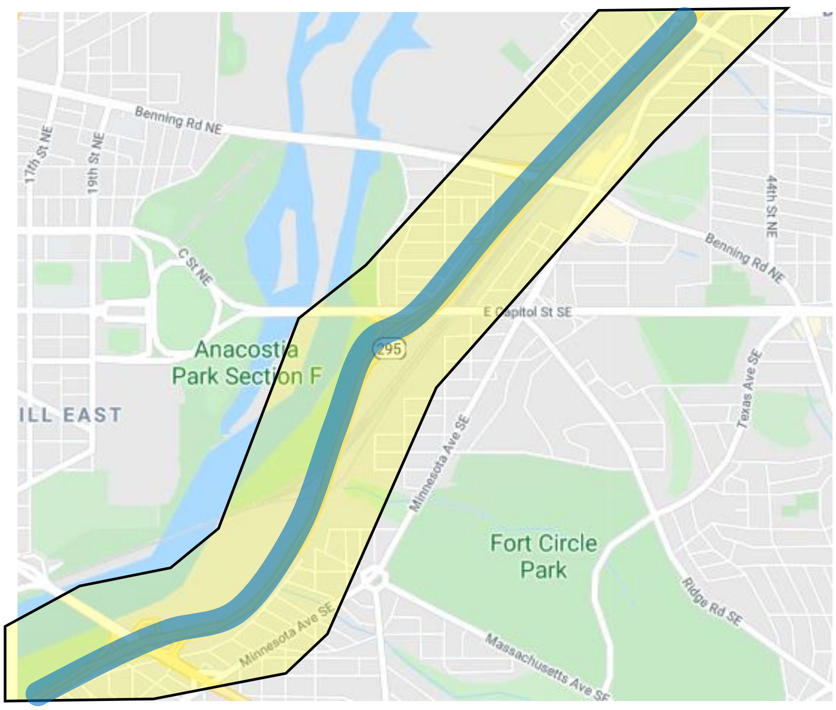
COPD (chronic obstructive pulmonary disease) vs. asthma

- ✓ COPD and asthma have similar symptoms. The main differences are that COPD tends to be an "all the time" chronic problem, while asthma is more likely to flare up due to triggers. COPD is more common in older adults, while asthma is more common in younger children.

Consider asking students if they know someone with one of these health issues. It is a good way to help make a personal connection, but be careful not to pry into personal health information.

5. **Areas of study.** Ask students what the different areas are that they are looking at with their data. Help them understand that they're looking at data in the area around a major roadway, starting from up to 200 feet away from the roadway, 200 feet to 1,000 feet away, and more than 1,000 feet mile away. Let's see what this means by looking at a map.

   Show students this map of Washington DC. The major roadway in this case is Route 295, which runs NE/SW through the middle of the map. The 200-foot distance from the roadway is in blue, and the 1,000-foot distance is in yellow. If you count the blocks, you can see that 200 feet from the road is less than a block. 1,000 feet is about 4 blocks.



   You can show students the distance in their own neighborhood by displaying a Google map of the area. Right click on a major roadway, then choose "measure distance". Click anywhere else and you will bring up a measuring tool. Move the second point around to see how far 200 feet and 1,000 feet are away from the major roadway.

6. **Analyzing the data.** Provide the students with the data that goes into the chart (see below). Keep in mind that these are fictional data points based on actual research.

TEACHER NOTES

Asthma and roadway study in Baltimore

- ✓ For a comprehensive analysis of how air pollution affects asthma rates in Baltimore, see this study published in 2017: https://www.environmentalintegrity.org/wp-content/uploads/2017/12/Baltimore-Asthma.pdf

Research sources

- ✓ For more information on the research sources used to generate the sample data in this activity, read the Introduction from this study: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4243518/

TEACHER NOTES

Differentiation

✓ There are many different ways you can divide students into groups to analyze the data. Have students work in pairs to analyze all the variables, or in groups to analyze all the variables, in pairs to analyze one variable, etc. You can also choose different grouping methods for different students. Choose the grouping that works best to support all your students.

Differentiation

✓ When students are analyzing their data, they are only expected to find the difference between values. Depending upon their grade level, students may also be able to determine ratios between values, or to calculate rate of change. When calculating rate of change, consider the most logical value for x in these circumstances, since the distances vary from 200 feet to 1,000 miles.

	People living within 200 feet of a major roadway	People living between 200 feet and 1,000 feet of a major roadway	People living beyond 1,000 feet of a major roadway
Cardiovascular disease rate	13.1%	10.4%	7.1%
Lung function in women (volume of air)	3,465 mL	3,477 mL	3,500 mL
% of children with asthma who went to the ER in the last year for asthma symptoms	75%	71%	51%
COPD rates (women)	9.1%	6.7%	5.1%

Have students analyze the data by answering the questions on their handout:

- Does the data you are looking at go up, down, or neither the FARTHER you go from the roadway?
- Does this mean the heath outcome gets better (healthier), worse (less healthy), or neither (no change)?
- How big is the difference?

7. **Graphing:** Have students create graphs showing the data. You can discuss with them what types of graphs to use. In this case, bar graphs work well. Line graphs are also possible, but be mindful of how to scale the x-axis based on the fact that the data points are at <200 feet, 200 feet-1,000 feet, and 1,000+ feet. If student computers are available, consider having students create the graphs on their computers.

8. **Causation vs. correlation:** Ask students whether they think that pollution from the roadway is **causing** the health **effects**. How do they know? Remind students that just because the data shows that people who live near roadways can have worse health outcomes, that doesn't mean the pollution caused their health problems. What other things from the road could be causing the health problems? (ex. noise). Is there any other reason people in the neighborhood might have health problems (ex. from a power plant in the area?). Proving **causation** (that the air pollution from the road is causing the health outcomes) is very difficult. It helps if they can explain how the pollution **might** cause the health problems.

Have students think back to the Lung Attack activity. What do they know about how particulate matter affects human lungs? How could they use this information to make an argument that the pollution is **causing** the health outcomes?

The key takeaway for students in the correlation/causation discussion should be that it may look like living near a roadway causes these heath outcomes, but scientists would need to run more tests on the people to determine if their symptoms are **caused by** the air pollution, or by some other factor or combination of factors.

9. **Sensemaking discussion:** Discuss with students what their conclusions are based on these data. Use the CER below to help guide the discussion, being clear to consider the correlation vs. causation idea (based on these data health effects are correlated to living near a roadway, but we can't say they're caused by the pollution without more information.

10. **Question check-in:** Take a moment to look back at the questions students generated during Activity 1. If there are any questions that you have answered, make sure to recognize this, and have students articulate a clear answer to the question. You may choose to use this in place of their formative assessment if appropriate.

11. **Formative Assessment:** Have students complete the Claim-Evidence-Reasoning statement on the last page of their handout. Their CER should focus on how living near a roadway affects human health based on these data. Scaffold the CER as necessary based on students' experience with the structure. Students should keep a narrow focus on one health outcome. Example CER:

    - Claim: Living near a major roadway can be bad for your health, possibly because of pollution from cars and trucks.

    - Evidence: People who live within 200 feet of a major roadway have a 6-percentage point higher rate of cardiovascular disease than people who live more than 1,000 feet away from a major roadway.

    - Reasoning: Air pollution (and possibly other pollution) from cars and trucks can get into people's lungs and then into their blood stream. This causes them to develop cardiovascular disease.

TEACHER NOTES

More on correlation vs. causation

- ✓ This discussion of correlation vs. causation is only a brief introduction. If you have taught the concept before, this is a good time to reinforce what you've taught before. If it's new to students (and you have more time) consider showing a video like this one: https://www.youtube.com/watch?v=VMUQSMFGBDo&t=205s

- ✓ If you plan to teach the other modules, Module 5, Activity 4 also discusses correlation vs. causation using graphs and a short reading.

Sensemaking

- ✓ For more tips on how to lead a sensemaking discussion, see the information at the front of the curriculum.

Name ______________________________

STUDENT HANDOUT

Citizen Science: How Particulate Matter Pollution Affects a Community

Data

	People living within 200 feet of a major roadway	People living between 200 feet and 1,000 feet of a major roadway	People living beyond 1,000 feet of a major roadway
Cardiovascular disease rate			
Lung function in women (volume of air)			
% of children with asthma who went to the ER in the last year for asthma symptoms			
COPD (bronchitis) rates (women)			

What do each of these health effects mean?

- Cardiovascular disease: ______________________________
- Lung function: ______________________________
- Childhood emergency room visits for asthma: ______________________________
- COPD (bronchitis): ______________________________

Analysis

For each variable, decide whether the data goes up, goes down, or neither the farther you get from the roadway:

- Cardiovascular disease: ______________________________
- Lung function: ______________________________
- Childhood emergency room visits for asthma: ______________________________
- COPD/bronchitis:______________________________

For each variable, decide whether the health outcome gets better (healthier), worse (less heathy), or neither the farther away you get from the roadway. Remember, just because a number goes up or down doesn't mean it's getting better or worse:

- Cardiovascular disease: ______________________________
- Lung function: ______________________________
- Childhood emergency room visits for asthma: ______________________________
- COPD/bronchitis:______________________________

For each variable, decide how big the difference in health outcome is between the 200-foot health outcomes and the 1,000-foot health outcomes (ex. what is the difference in the numbers?). Write the difference as a part of a complete sentence (ex. the cardiovascular disease rate is <blank> percent lower/higher at less than 200 feet away compared to 1,000 or more feet away.)

- Cardiovascular disease: ______________________________
  ____
- Childhood emergency room visits for asthma: ______________________________
  ____
- Lung function: ______________________________
  ____
- Premature births: ______________________________
  ____

Create graphs of each variable using graph paper provided by your teacher, or use a computer to make your graphs.

Conclusions

Based on these data, do you think that living near a major roadway poses a health risk to humans? Write a claim-evidence-reasoning statement to make an argument based on your research. Use the guide below to help with your statement:

> Claim: Your claim should answer the question about whether living near a roadway poses a health risk.
>
> Evidence: Your evidence should use data from the activity to support your claim.
>
> Reasoning: Your reasoning should explain how your evidence supports your claim. It should answer the question: how can living near a roadway affect a person's health? You will need to use information you learned earlier in the investigation for your reasoning.

Activity 6 (Elaborate): Air Toxics in the Community (optional)

Activity summary: In this optional activity, students learn about toxic air pollution, which can cause more acute health effects such as cancer. They do this by watching two videos showing real world examples of how air toxics have affected a community, and comparing the two situations. They also learn about how communities can advocate for themselves when air quality issues arise.

Standards Connection
DCI: ESS3.C: Human Impacts on Earth Systems

Warmup: What does this symbol mean and where have you seen it before?

- Poison, danger, toxic (make sure students all know the word "toxic")
- On chemical bottles, on cleaning products, at a factory, etc.

1. **Frame the Activity:** Tell students that particulate matter from combustion vehicles isn't the only kind of air pollution that can be dangerous to a community. Today they are going to learn about two real world situations in which toxic chemicals affected a community, and what community members did to advocate for themselves when they found out there was a problem with air pollution.

2. **Air Pollution in Portland:** Hand out the "Air Toxics in the Community" sheet for students to use to take notes on the videos. Have them take a moment to review the information they'll be collecting from the video. When they are ready, show the video: "How moss revealed an undetected air pollution threat in Portland" https://www.youtube.com/watch?v=jHy2qcxDLDM

   After the video, lead a brief discussion on what they learned about the air pollution problem in Portland, and what the community did about it.

   - What are the toxic chemicals? heavy toxic metals (Cadmium, Arsenic)
   - Where did they came from? Artisan glass manufacturing companies
   - What were the health effects? Kidney damage, lung cancer
   - Who first identified the pollution problem? US Forest service scientists (Sarah Jovan)

ACTIVITY DETAILS

Time: 45 minutes

Objectives
- ✓ Students will learn how scientists identify sources of toxic chemicals in the community
- ✓ Students will understand the difference between the criteria pollutants and toxic chemical pollutants

Materials
- ✓ Computer & projector
- ✓ Speakers

Handouts
- ✓ Air Toxics in the Community
- ✓ Air Toxics and Criteria Pollutants

TEACHER NOTES

Additional Media

- ✓ The Smokestack Effect Part 2 provides some additional information about local air quality testing and what individuals can do if they are concerned about air pollution and its effects on children: https://www.youtube.com/watch?v=KO_jz1RyQwk

Modifications

- ✓ If students are interested in learning more about what chemicals count as air toxics, you can show them this list of the 187 hazardous air pollutants from the EPA: https://www.epa.gov/haps/initial-list-hazardous-air-pollutants-modifications While most of these chemicals will be unfamiliar to students, they will probably recognize things like chlorine, cyanide, and mercury

- How did they discover the pollution? moss had filtered pollution out of the air
- How did scientists studied the problem? analyzed moss samples from across the city
- How did the government follow up? set up air quality monitors
- How did the community respond (what did they do?): ask the state to setup air monitors, meet together, hold rallies/make signs

3. **Air Pollution in Addyston:** Tell students that they are about to watch another video of a community affected by air pollution. After this video, they will compare and contrast the two scenarios, so they should keep an eye out for similarities and differences as they watch. Show the video: "The Smokestack Effect: Part 1" https://www.youtube.com/watch?v=Zxm_-TxrhKI

   After the video, lead a brief discussion on what they learned about the air pollution problem in Addyston, and what the community did about it.
   - What are the toxic chemicals? They are not specifically named
   - Where did they come from? a local plastics factory
   - Health effects of the pollution: cancer
   - Who first identified the pollution problem? reporters from USA Today
   - How did they discover the problem? matching EPA data with school locations using a model
   - How did scientists study the pollution? set up air quality monitors
   - How did the government follow up? they issued orders to the company to change
   - How did the community respond (what did they do?): they closed the school

4. **Compare and contrast:** Give students time to answer the compare and contrast questions on the back of their handout.

5. **Air toxics vs. criteria pollutants:** Hand out the reading "Air Toxics and Criteria Pollutants." Give students time to complete the reading and fill in the Venn diagram. When they are done, discuss the differences to ensure student understanding.

6. **Formative assessment:** Have students answer the "What would YOU do?" questions at the bottom of the Air Toxics in the Community sheet. It is worth taking the time to review students' answers to these questions, as this topic will come back near the end of the module. It is also important for students to recognize that individual citizens have the power to improve the environmental quality of their communities if they have the right knowledge.
    - **Who would you talk to?** Parents, teachers, your doctor, government agency (ex. MDE, DOEE, VA DEQ)
    - **What would you ask them to do?** Set up air quality monitors in the community or near the suspected source; check to see if you or other people in the community have health problems that might be connected to the pollution
    - **What could your community do?** Talk to government officials and ask for an investigation; talk to reporters about the problem; hold protests or rallies about the pollution; have community meetings to teach others about the problem

TEACHER NOTES

Looking ahead

- ✓ In the next activity (Who is Polluting in My Neighborhood), students have a chance to look up whether there are air pollution sources in their community. If you plan to do that activity, be sure to have students look at the "Air Toxins" tab to identify if there are any sources of toxic air pollutants in their community. If you don't plan to do that activity, you may want to look up any sources on your own before this activity so you can share that information with students. If you do, be cautious and tactful – sharing information that there is a source of potentially harmful air pollution in the community is a serious matter and should be introduced thoughtfully.

Name ______________________________

STUDENT HANDOUT

Air Toxics in the Community

Scenario 1: Portland, Oregon	Scenario 2: Addyston, Ohio
What are the toxic chemicals?	The specific names of the toxic chemicals are not mentioned in this video.
Where did they came from?	Where did they came from?
What are the health effects?	What are the health effects?
Who first identified the pollution problem?	Who first identified the pollution problem?
How did they discover the problem?	How did they discover the problem?
How did scientists study the pollution?	How did scientists study the pollution?
How did the government follow up?	How did the government follow up?
How did the community respond (what did they do?)	How did the community respond (what did they do?)

Compare & Contrast

What is similar the air pollution problems in Portland and Addyston?

What is different about the air pollution problems in Portland and Addyston?

What would YOU do?

If you believed there was toxic air pollution in your community, who would you talk to?

What would you ask them to do?

What kinds of things could your community do if they found out there was toxic air pollution?

Name ____________________

STUDENT HANDOUT

Air Toxics and Criteria Pollutants

What are Air Toxics?

Hazardous air pollutants, also known as toxic air pollutants or air toxics, are pollutants that cause or may cause cancer or other serious health effects. They may also cause damage to the environment. Toxic air pollutants are in things like gasoline and paint strippers. They are also used by different businesses such as dry cleaners. The US Environmental Protection Agency (EPA) is required to control 187 different hazardous air pollutants.

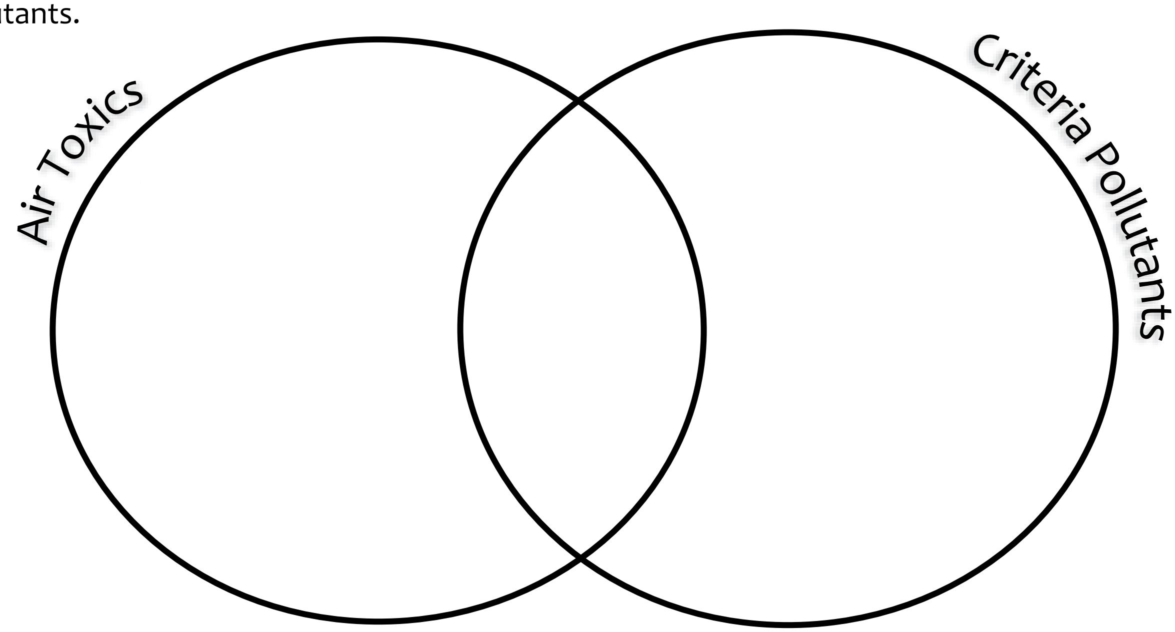
Where do Air Toxics Come From?

Most air toxics come from human-made sources, including mobile sources (e.g., cars, trucks, buses) and stationary sources (e.g., factories, refineries, power plants), as well as indoor sources (e.g., building materials and activities such as cleaning).

How are Air Toxics Different from Criteria Pollutants?

Criteria air pollutants are more common than air toxics, and they are less harmful in small amounts than air toxics. They are found all over the world, and they come from many different sources. There are only 6 criteria pollutants: particulate matter, ground-level ozone, carbon monoxide, sulfur dioxide, nitrogen dioxide, and lead. Like air toxics, the criteria pollutants can hurt human health and cause environmental damage, so they are also regulated by the EPA.

Fill in the Venn diagram below based upon what you know about air toxics and criteria pollutants.



Sources: Pollutants and Sources, US EPA: https://www3.epa.gov/airtoxics/pollsour.html
Managing Air Quality – Air Pollutant Types, US EPA: https://www.epa.gov/air-quality-management-process/managing-air-quality-air-pollutant-types

Activity 7 (Elaborate): Who is Polluting in My Neighborhood? (optional)

Activity summary: In this activity, students use a database to find local sources of air pollution. They identify who the polluters are, what type of industry they come from, what the pollutants are they emit, and how much. By comparing these data to other polluters, students can determine how much their local polluters contribute to air pollution in the community.

Standards Connection
DCI: ESS3.C: Human Impacts on Earth Systems
SEP: Analyzing Data

To do in advance: Use the local air pollution database to identify at least one local source of air pollution. You can access the database here: https://tinyurl.com/DCMetroAirPollution. Sort or search by zip code, town, or county to find pollution sources in your area. You can choose to use the tabs for criteria pollutants or air toxics, although students will use the criteria pollutants for their investigation.

Warmup: Name four sources of air pollution.

- Transportation (cars, trucks, boats, planes, etc.), power plants, chemical plants, fires, etc.
- The purpose of this warm-up is to help focus students' attention back on sources of air pollution before they begin researching in their own community

1. **Frame the Activity**: Choose a major local source of air pollution from the research you've done beforehand. Try to choose something that students may have heard of or know about: this can be a power plant, a chemical plant, or a local manufacturer. Ask students if they've ever heard of the company or building. If you can find a picture of the building, show that to students as well. Ask them what they know about the source you've chosen. They may know where it is or what it does. Ask students if they know whether the source produces air pollution or what kind of pollution it makes. Tell students that it's important for members of the community to know if there are sources of pollution nearby and how dangerous they are. They already know that the trucks from their investigation contribute pollution to the community. Today they're going to research stationary (non-moving) sources of air pollution to see if they are affecting the community as well.

ACTIVITY DETAILS

Time: 30-45 minutes

Objectives

- ✓ Students will research air pollution sources in their communities and analyze their findings

Materials

- ✓ Computer & projector
- ✓ Student computers (highly recommended)

Handouts

- ✓ Air Pollution Sources in My Community

Modifications

- ✓ If student computers are not available, you can search for local pollution sources using the database and print out a set for students to use.

Modifications

- ✓ The directions for the community database use zip code to find local pollution sources, but you can also use town or county. Check out the database in advance to know what search is best to use.

TEACHER NOTES

Source data

✓ The information for the local pollution source database comes from the National Emissions Inventory published by the US EPA. The database is updated every three years. These data come from the 2017 version of the database. Learn more about the NEI here: https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei

Modifications

✓ There are all different ways students can interact with the database if you choose to take the time to teach them how to use Google Sheets. For example, they can filter by county to isolate local sources and then sort to see what industries are the greatest polluters in the area, or identify what pollutants are emitted most in their area. You can also have them use the Air Toxics tab to find hazardous pollutant emissions in the community and then Google their health effects.

2. **Community air pollution database:** Hand out the Air Pollution Sources in My Community sheet to students, along with student computers (if available). You may want to review the directions with students before having them begin the activity. You can also go through the first few steps with them to make sure they are on the right track. In general, students will search for information about local pollution sources, identify the kinds of pollution they are emitting, and how much.

3. **Analysis**: Have students answer the analysis questions to identify the type of industry and the pollutant that is most common in their area. They should also compare their local data to that of the biggest polluters in the database. For reference:
   - Electricity generation (power plants) is the largest type of emitter.
   - The most common pollutants from these sources are nitrogen oxides (NO_x) and Sulfur dioxide (SO_2).

4. **Discussion:** Give students a chance to share what they learned from their research. They may say they learned what industry is the greatest polluter in their area, or how much a local factory emits. Ask them questions about how this makes them feel. Were they surprised by the number of polluters in the area, or is their community relatively free of pollution sources?

5. **Question check-in:** Take a moment to look back at the questions students generated during Activity 1. If there are any questions that you have answered, make sure to recognize this, and have students articulate a clear answer to the question. You may choose to use this in place of their formative assessment if appropriate.

6. **Formative assessment:** Have students answer the following prompt: We know that transportation from cars and trucks like the ones we are studying, and also electricity generation are two of the biggest sources of air pollution. Why do you think these two sources of pollution are so big? What could you do to help reduce pollution from these sources? (Hint: what do you need every day that is transported from somewhere else?)
   - The goal of this formative assessment is to help students make the connection between human activities and air pollution. The reason these sources of pollution are so high is because we drive a lot, we transport a lot of things (food is the thing they use every day), and we use a lot of electricity. To shrink these sources, we can drive less, use less electricity, and eat locally produced food.

Name ______________________________

Air Pollution Sources in My Community

Directions:

1. Using your computer, go to the website: https://tinyurl.com/DCMetroAirPollution. You should see a spreadsheet of information that looks like this:

	A	B	C	D	E	F	G	H	I	
1	state	county	site name	facility source type	city	zip coc	pollutant desc	pollutant type(	total en	emissions unit of measure
681	MD	Baltimore city	CURTIS BAY	Rail Yard	Unknown	0	Nitrogen Oxides	CAP	91	TON
682	MD	Baltimore city	P Q Corporation		Baltimore	21230	Nitrogen Oxides	CAP	84	TON
705	MD	Baltimore city	Buckeye Terminals, LLC - Baltimo	Petroleum Storage Faci	Baltimore	21226	Volatile Organic Compounds	CAP	40	TON
706	MD	Baltimore city	American Sugar Refining	Sugar Mill	Baltimore	21230	Carbon Monoxide	CAP	40	TON
730	MD	Baltimore city	BAYVIEW (NS)	Rail Yard	Unknown	0	Nitrogen Oxides	CAP	26	TON
745	MD	Baltimore city	PIER 7	Airport	BALTIMORE	0	Lead	CAP/HAP	20	LB
747	MD	Baltimore city	Buckeye Terminals, LLC - Baltimo	Petroleum Storage Faci	Baltimore	21226	Carbon Monoxide	CAP	20	TON
752	MD	Baltimore city	American Sugar Refining	Sugar Mill	Baltimore	21230	Nitrogen Oxides	CAP	19	TON
766	MD	Baltimore city	Johns Hopkins Univ. - Charles Str	Institutional (school, h	Baltimore	21218	Nitrogen Oxides	CAP	19	TON
768	MD	Baltimore city	Crispy Bagel Company	Bakeries	Baltimore	21223	Volatile Organic Compounds	CAP	15	TON
793	MD	Baltimore city	CURTIS BAY	Rail Yard	Unknown	0	Carbon Monoxide	CAP	14	TON
799	MD	Baltimore city	American Sugar Refining	Sugar Mill	Baltimore	21230	Carbon Monoxide	CAP	11	TON
803	MD	Baltimore city	American Sugar Refining	Sugar Mill	Baltimore	21230	Carbon Monoxide	CAP	10	TON
804	MD	Baltimore city	American Sugar Refining	Sugar Mill	Baltimore	21230	Carbon Monoxide	CAP	9	TON
823	MD	Baltimore city	American Sugar Refining	Sugar Mill	Baltimore	21230	Nitrogen Oxides	CAP	9	TON
828	MD	Baltimore city	American Sugar Refining	Sugar Mill	Baltimore	21230	Nitrogen Oxides	CAP	8	TON

This is a list of all the pollution sources in Maryland, Virginia, Washington DC, and West Virginia. Make sure you are on the tab for Criteria Pollutants (look at the bottom).

2. To find pollution sources in your neighborhood, start by sorting the list by zip code. You can do that by clicking on the little triangle next to zip code that looks like this:

   Then click Sort A→Z. This will sort the list by zip code.

3. Now you can scroll through the list to find your zip code. You can also search for your zip code by holding <control>-F, typing your zip code into the box that pops up, and hitting enter. When you find some entries in the list for your zip code, go to the next step. If you can't find anything in your zip code, use one that has a similar number.

4. When you find some emissions sources in your zip code or one nearby, look in the column for "total emissions" (it is the next to last column). This is the amount of emissions that come from that source. Find the source with the most emissions in your area.

5. Write down the following information for that source in your data table on the next page:
   - **The site name:** this is the name of the company or organization
   - **Type**: this is what the company or organization does
   - **Pollutant**
   - **Total emissions**

6. Find at least four other sources of pollution in your neighborhood, and add their information to your data table. Look for sites you recognize from your neighborhood, and sites that have a lot of emissions.

<u>Pollution Sources</u>

Site Name	Type	Pollutant	Total emissions

<u>Analysis</u>

What "type" of polluter is most common in your area? ______________________________

What pollutant was most common in your area? ______________________________

Sort the database by total emissions by clicking the arrow next to total emissions and choosing "sort Z→A". When the database is sorted, look at the top 10 polluters.

What "type" of industry creates the most pollution? ______________________________

What pollutants are most common from this industry? ______________________________

How do the polluters in your area compare to the biggest polluters? Do the emit a lot or a little pollution in comparison? ______________________________

Activity 8 (Elaborate): Not In My Backyard: Environmental Justice

Activity summary: In this activity, students investigate whether environmental injustice may be happening in their communities by using the EPA's EJ Screen Tool. They will examine a series of maps and graphs to compare pollution levels and demographics in these areas in order to reach their conclusions.

Standards Connection
DCI: ESS3.C: Human Impacts on Earth Systems
SEP: Analyzing Data, Engaging in Argument from Evidence

Warmup: What does justice mean to you? When have you heard the word justice used before?

- Focus on ideas such as equity and fairness. Students may have heard terms like "social justice" or "criminal justice" and they may associate justice with the legal system. The goal of this warmup is to help frame the discussion of environmental justice, but be careful not to let the conversation get too caught up in the complexity of what justice means.

1. **Frame the activity:** Ask students how they would feel if someone decided to build a new major highway through their neighborhood? Remind them that if we want to go places, then highways need to be put somewhere. What about a new power plant or factory? Did they ever wonder who decides where these things go, and how they decide where to put them? Write the acronym NIMBY (Not In My BackYard) on the board and explain what it stands for to students. Tell that that in this activity, they're going to look at some maps to see whether some people face more air pollution that others and if sources of air pollution like trucks on highways are fairly placed in our communities. We call this idea Environmental Justice. Put the words Environmental Justice up on word wall.

Low tech and High tech

For this activity, students will use maps from the EPA's online Environmental Justice Screen tool. If student computers are available, they will look up the information themselves. If computers are not available, you will need to have students look on the projector as you use the tool, or print out versions of the maps for students to use. The directions below are based on using student computers, but what students will do with the maps is essentially the same either way.

ACTIVITY DETAILS

Time: 45-60 minutes

Objectives

- ✓ Students will understand the concept of environmental justice
- ✓ Students will investigate environmental justice in their community to see if certain groups of people are more frequently affected by air pollution

Materials

- ✓ Student computers (highly recommended)
- ✓ Computer & projector
- ✓ Internet connection

Handouts

- ✓ Environmental Justice investigation guide

Teacher Tip

- ✓ Make sure to go through the EJ Screen activity yourself before having students do it. The EJ Screen tool is relatively easy to use, but it is good to be familiar with the controls so you can help students.

TEACHER NOTES

Differentiation

✓ Some students may be comfortable following the directions right from their investigation sheet, while others will need more support. Choose the level of support for your students that works best for them. The directions as written here mirror what is in the student directions.

Accessibility Awareness

✓ EJ Screen uses colors for scale that will likely be difficult for colorblind students to see. You may want to pair any colorblind students with a partner to help with this. On some maps you can change the color coding; make sure to point this out as it will help as well.

Cultural Awareness

✓ EJ Screen uses the term "minority population" which carries some negative connotations. Students may also not be familiar with this term. You may want to discuss the term with them, including why it is or isn't used today.

2. **Introduction to EJ Screen:** Pass out the Environmental Justice Investigation Sheet to students. Tell students that the EPA has a tool to help citizen scientists like them to determine if there is environmental injustice going on in their community. The tool is called EJ Screen. They're going to use EJ Screen to find out if there is environmental injustice in their community or others around them. Pass out student computers and have students go to the EJ Screen tool here: https://ejscreen.epa.gov/mapper/ Then have them type in their city/town or zip code in the box in the top right to center the map on their neighborhood.

3. **Particulate matter and ozone maps.** Have students follow the directions for adding PM 2.5 to their maps. When they are done, they will write down the percentile that the neighborhood falls into for PM 2.5. The percentile related how the neighborhood compares in amount of PM 2.5 to other neighborhoods around the country. Note that the higher the percentile, the higher the amount of PM 2.5. After students have looked up the information, make sure to go over the concept of percentile with students, as it can be confusing. When students see the big red area for PM 2.5, they should have an idea that there might be a power plant or other major source of PM in that community. For ozone, they should recognize that ozone levels are high in the corridor between Baltimore and Philadelphia. This is likely due to high traffic volumes between these two cities.
4. **Demographics:** When looking at demographics, students should notice that areas with high minority populations and high numbers of low-income individuals tend to be in or near major cities like Washington, DC and Philadelphia.

What it Means to Investigate Injustice

The process of investigating injustice is both very powerful and at times very disheartening. As students look and possibly find environmental injustice, be mindful both of how this may affect them, and how it may empower them to advocate for change. This activity can have a tremendous impact on student thinking. Make sure that impact is one that honors their individual situation and teaches them how they can advocate for their communities.

5. **Side-by-side maps:** When students are looking at the side-by-side maps of the Diesel PM and the Demographic Index, they should be able to see some overlap between these two maps, especially in places like SE Washington DC and Baltimore.

6. **EJ Indexes:** Many of the environmental indicators that students look at will show potential environmental injustice, often because the pollutants come from the same source. Ozone and Diesel PM are important because they are the result of trucks and other traffic that students are investigating in this module.

7. **Neighborhood reports:** The reports tool can be especially valuable, because it allows students to look at all the indicators for one place at the same time. By looking at two different neighborhoods, they can see the big differences in the bar graphs for the environmental indicators. You may need to help students consider what neighborhoods to look at to see the differences. If you want to print out versions of these reports, click "Get printable standard report" instead of "Explore Reports" This will give you a nicely formatted report with the percentiles for EJ Index, demographics, and environmental indicators, as well as a map of the EJ Index.

8. **Sensemaking discussion:** Once students have finished their research, bring them together to discuss what they learned. Be sure to reference data that students explored, and to push them to use data to support their position on environmental injustice. Here are some questions you might use to guide the discussion:

   - What did you learn from this activity?
   - Do you think environmental injustice is real, and if so, is it happening in your neighborhood?
   - How does this information relate back to your own citizen science work in investigating the polluting trucks?
   - If there is environmental injustice happening, what can you do about it?

9. **Formative Assessment**: Have students answer the prompt in the Drawing conclusions part of their guide: Do you think there is environmental injustice in the DC-Baltimore area? (do all people have the same amount of pollution in their communities?) Use at least three pieces of evidence from our activity today to support your answer.

TEACHER NOTES

Modifications

✓ There are many different things you can do with EJ Screen. This activity is just a beginning. If you have time, consider other ways you might use EJ Screen to teach about environmental injustice. You can look at specific neighborhoods, or look for sources of pollution in your neighborhood (ex. click add maps, additional layers, sites reporting to EPA. Check the box for toxic releases to see the sites that release toxic chemicals)

Name ______________________________

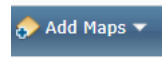
STUDENT GUIDE

Environmental Justice Investigation Guide

Directions:

1. Using your computer, go to the EJScreen website: https://ejscreen.epa.gov/mapper/

2. In the top right corner where it says, "Find an address or place" type in your city or town and click the name of the town when it pops up. You can also use your zip code for a closer map. You should see the map move to show your city or neighborhood.

3. Click the button at the top that says "Add Maps". It looks like this: 

From the dropdown menu, choose EJSCREEN Maps. A box will pop up that has a list of many different maps to choose from. Since we are studying particulate matter from trucks, click PM 2.5 and click "Add to Map".

4. The map you see now shows how the amount of PM 2.5 in your neighborhood compares to the amount in other parts of the country. Use the scale that popped up on the right side to match the color on the map with the percentile for your neighborhood. Write the percentile in the space below.

   PM 2.5 in my neighborhood:____________________

   This means that your neighborhood has more PM 2.5 pollution than the same percent of neighborhoods around the country. For example, if your percentile is in the 80-90 range, then it means that 80-90% of the neighborhoods in the country have less PM 2.5 in their air than you do.

5. Zoom out by clicking the minus sign in the top left of your screen. Keep zooming out until you can see all of Maryland, Virginia, and Pennsylvania. Do you see a big red spot of PM 2.5 pollution near Harrisburg? What do you think might be there?

   ____

6. Change the map from PM 2.5 to Ozone by clicking Ozone in the box on the left and clicking "Add to Map". Stay zoomed out so you can see the whole area. In what areas is ground-level ozone a problem?

   ____

   Why do you think it's a problem here? (hint: think about what people do a lot of in this area that might cause a lot of air pollution)______________________________________

   ____

   ____

7. In the box on the left-hand side, click “Demographic Indicators.” This will bring up a list of characteristics about people. Look at the maps for Minority Population and Low-Income Population. Where do you see high minority populations (people of color) and low-income populations?

8. Zoom back in on the area where your school is (you may need to put the town back into the search in the top right). What can you tell about the demographics of the neighborhood around the school?

9. At the top of the screen, click “Add maps” and then choose Side-by-Side maps. This will bring up two maps where you can look at different things at the same time. In the top left of the screen, click Map Data (it looks like this: Map Data ▼ hoose the Environmental Indicator for NATA Diesel PM. Then click Update Map. Diesel PM is particulate matter from vehicles like trucks that use diesel fuel. What do you notice about where Diesel PM is bad?

10. On the right-hand map, click the Map Data button, and make sure the top button is on EJSCREEN Maps. Then choose Demographic Indicators and Demographic Index, and click Update Map. Demographic Index shows where people of color and low-income people live. Make sure you are zoomed out so you can see the whole DC-Baltimore area. Compare the two maps. Where are the colors the same in both maps?

If the colors are in the sample places it means that people of color and low-income people live in places where there is a lot of air pollution. This is a sign of environmental injustice. Environmental injustice means that some people are affected more by pollution than others in a way that is unfair.

11. Go back to your original one map and in the pop-up on the left, choose EJ Indexes. EJ Indexes are like combining the two maps you just looked at into one map. If the colors on the map are in the yellow or red zone, it means environmental injustice may be happening in that community. Choose different pollutants for the EJ Index and click Add to Map. Which pollutants likely cause the most environmental injustice?

12. Use the location search in the top right of the screen to go back to the neighborhood where your school is. Then click the “Select Location” button at the top of the screen. Click Select Location again from the dropdown menu. A little box will pop up. Make sure the little pin is selected, and then click on the map near where you think the school is located. A little box will pop up. In the box, click “Explore Reports”. This will bring up reports about environmental justice in the area that look like this:

Look at the data in the bar graphs. This shows the percentiles for all the pollution within 1 mile of the pin you put in the map. What are the highest pollution indicators near your school?

Click where it says EJ Indexes in the reports box. This shows whether there is likely to be environmental injustice in the area near your school. The higher the percentiles, the higher the risk of environmental injustice. Based on the percentiles, do you think there is environmental injustice happening in your community? If so, write down the EJ Index for the pollutants you think show environmental injustice may be happening.

13. Move the map to a different neighborhood that you think may be different than yours. Do the same thing you did with your neighborhood: click select location, then put a pin in that neighborhood and click Explore Reports from the box that pops up. Look at the environmental indicators for this neighborhood. How do they compare to the indicators in your neighborhood?

Click on the tab in the reports box that says EJ Indexes. What are the indexes like here compared to in your neighborhood? Do you think environmental injustice is happening here?

Drawing conclusions

Based on your research today, do you think there is environmental injustice in the DC-Baltimore area? (do all people have the same amount of pollution in their communities?) Use at least three pieces of evidence from our activity today to support your answer.

Activity 9 (Evaluate): Public Hearing on Banning Diesel Trucks

ACTIVITY DETAILS

Time: 2-3 class periods

Objectives

- ✓ Students will explore and learn different perspectives on public policy related to air quality
- ✓ Students will make arguments based on evidence about whether or not diesel trucks should be banned in the community

Materials

- ✓ Role play stakeholder cards (print out and cut up enough so each student has one)
- ✓ Student computers (optional for research and writing statements)
- ✓ Research materials
- ✓ Presentation rubric

Handouts

- ✓ Diesel truck ban role play scenario
- ✓ Role-play planning
- ✓ Hearing notes sheet
- ✓ Cast your vote writing prompt
- ✓ News article about California's ban on diesel truck manufacturing (optional): https://arstechnica.com/cars/2020/06/california-set-to-ban-all-heavy-diesel-trucks-and-vans-by-2045/

Activity summary: In this multi-day activity, students take on the roles of different stakeholders in order to participate in a state committee hearing on whether or not to ban diesel trucks from traveling through residential communities. After taking on a role, they use their notes and additional resources to research their position. Next, they write a statement for their character. Finally, they hold the hearing, with some students acting as committee members who ask questions, and others reading their statements.

<u>Standards Connection</u>

DCI: ESS3.C: Human Impacts on Earth Systems
SEP: Engaging in Argument from Evidence
CCC: Cause & Effect

Warmup: The stakeholders for a school are the students, teachers, administrators, parents, the government, and interested community members. Based on this list, what do you think a "stakeholder" is?

- Use responses to help students understand that a stakeholder is someone who has an interest in a particular thing like a business, a policy, etc. That interest is usually based on the fact that it affects their lives in some way – ex. how they earn a living, their health, their future, etc.

1. **Frame the activity:** We have spent the last week (or more) studying air pollution in a community, especially air pollution that comes from vehicles like trucks. We studied particulate matter and how it can affect people and a community. Now it is your chance to raise your voice about what we should do about the trucks and the air pollution they create. During the next two days, we are going to role play a fictional scenario of a government hearing to decide if diesel trucks should be banned from traveling through residential communities. First you will learn about all the different stakeholders, from people in the community to truck drivers. After we have learned about our roles, you will hold a meeting to decide whether or not the trucks should be banned. Everyone will participate in the meeting based on the role that you have.

2. **Introduce the scenario:** Share the role play scenario with students and read it together. Make sure all students understand the details of the scenario. Students should immediately start making connections with what they have learned throughout the module. Do your best to answer any questions students, and feel free to improvise as necessary.

3. **Identifying stakeholders:** Ask students what stakeholders they think would be involved in this scenario. Give them a moment to write down a list on their scenario sheets. When they are ready, have students share their ideas, and write them on the board. Use questioning and discussion techniques to help them think of a robust list of potential stakeholders, especially different people that work in the shipping industry or that ship their products with trucks. Also consider everyday citizens, and government officials of the cities, towns, and counties in the state.

   Once the stakeholder list is created, tell students that they will each take on the role of one of these stakeholders for this activity. They will have time to learn about their stakeholder, and do some additional planning and research to think about what their stakeholder might say at the permit meeting.

4. **Assigning roles:** Give each student a role card from the scenario (or have them choose one). If any roles you identified earlier in the activity are not on a card, allow students to choose that stakeholder as well. Have students share their role with the class so they all know what roles they are playing. Make sure the State Committee Members know that they will be the ones listening to the other stakeholders during the meeting (they will not write statements)

5. **Researching roles:** Hand out the Role Play Planning sheet, and give students time to develop their characters by:
   - Giving themself a name
   - Talking to other people with similar roles or others who may be able to provide information for them. For example, citizens may want to talk to the health researchers or the environmental scientists
   - Deciding if they want the committee to vote for or against the ban
   - Doing research on diesel trucks (see handout for details)
   - Creating a written statement that they will read, or points that they would like to make, including their position. (Note: Committee members should create questions to ask the other stakeholders during the meeting.)

6. **Writing statements:** Once students have finished their research, have them write a statement from their character's point of view. Encourage them to think of what arguments their character would make, either in favor of or against the ban. They should use information from their research to support their statements.

TEACHER NOTES

Differentiation

✓ Consider what roles may be easier or more difficult to play for individual students, and assign those roles accordingly.

Advance planning

✓ You may want to have some resources available to assist students with their research including articles (see materials) or websites. Remind students to look back in their notes for information as well. A fact sheet from the Maryland 2015 Strategic Goods Movement Plan is attached and may be helpful to some stakeholders

Getting into the role play

✓ Consider different ways that you can help students get into their roles. For example, you may get name tags and have students put their fake name and role on the name tag so they can more easily identify one another.

TEACHER NOTES

Modification

✓ Instead of having some students act as committee members, have experts on the topic (ex. government officials, researchers, etc.) join the class for the hearing to act as committee members.

Modification

✓ If you have a large class, consider having students work in pairs to deliver a joint statement.

12. **Preparing for the hearing:** The day of the hearing, the teacher will play the role of a state official who will run the meeting but who does not have a vote at the end. Before starting the meeting, make sure all students are prepared to participate (they have notes, a prepared statement, etc.) Arrange the classroom so that the committee members can sit facing the rest of the class. Provide a place for stakeholders to speak from. You may want to create a sign-up sheet so that you can call on stakeholders when it is their turn. Hand out the notes sheet to students and tell them that they will be writing their own letter or decision (whether or not to ban the trucks) after the meeting, so they are required to take notes during the meeting on reasons for or against the ban.

13. **Hold the hearing.** Calls the meeting to order, and provides a brief statement about what the meeting is for. Tell stakeholders that they will come up to the podium, tell everyone their name and what their role is, and then make their statement. Committee members may have questions for them. A government official (the teacher) will keep track of time.

    During the meeting, you may choose to use attached rubric to assess students on their statement, including their answers to questions that the council members ask. If necessary, you can prompt the council members to ask questions, or you can ask yourself. Keep time to make sure the meeting moves forward and all students have a chance to present. Council members can be assessed based on how well they ask appropriate questions and interact with the presenters.

14. **After the meeting:** Thank all the students for their participation in the committee meeting. Tell them that they will have the next period (or more) to write their final statement about whether the permit should be approved or not (see next activity). They should write the statement from *their own perspective*, not the perspective of their characters. After all the assignments have been turned in, they will tally the votes to see whether the permit is approved or not.

15. **Casting their votes:** Provide students with the final writing prompt to do either in class, or at home. The writing prompt asks students to vote for or against the ban, and then use evidence from the committee meeting and the rest of this investigation to support their decision. Their evidence should include:
    - What particulate matter is and how it affects the human body
    - Where particulate matter comes from
    - Any additional details required to support your argument for or against banning diesel trucks from residential neighborhoods

Review the prompt with students, and review the writing rubric with them (it is very similar to the presentation rubric). You may choose to allow them to use their committee statements to help them write their final vote statements – the committee statement will work well as a first draft.

TEACHER NOTES

Tallying the Votes

- ✓ Don't forget to tally the votes at the end of the module to let the students know the results of their hearing!

STUDENT GUIDE

Diesel Truck Ban Role Play Scenario

Scenario: The state government has been studying the problem of particulate matter pollution, and has decided that they should do something about it. After listening to different stakeholders, they have decided to consider a new law to ban diesel trucks from traveling through residential neighborhoods in the state by 2030. To consider this proposal, they will hold an open public meeting where different stakeholders will share their opinions with the state government committee. After the meeting they will vote on whether to move the bill forward.

Stakeholders:

The Committee Meeting:

- The state is considering a new low to ban diesel trucks from driving through residential neighborhoods in the state by 2020. The State Government Committee of Environment & Transportation is holding a hearing to get public comments before they vote on for or against the bill. Stakeholders are encouraged to attend to the meeting to provide input into the decision.

Name ______________________________

STUDENT GUIDE

Role Play Planning

What is your character's name? ______________________________

What is his/her role? ______________________________

Do you want the committee to vote for the ban or against the ban?______________

When doing your research, consider your role. What kind of information should you know? Here are some questions to consider researching:

- How many diesel trucks are used in the state?
- What alternatives are there to diesel trucks?
- How much do diesel trucks cost? How much would this alternative cost?
- What can the state do to help make this cost lower?
- Why kind of air pollution do diesel trucks emit?
- What are the health effects of this pollution?
- What is the effect of this pollution on the environment?

My Statement (or questions for committee members):

Remember to consider your role, and to use evidence to support your argument.

Name ______________________________

STUDENT GUIDE

Hearing Notes Sheet

Reasons to ban diesel trucks	Reasons NOT to ban diesel trucks

Student Name________________________________

Diesel Truck Ban Presentation Rubric

Project area	Beginning	Needs Improvement	Proficient	Advanced
Factual accuracy	Student's statements have significant factual inaccuracies.	Student's statements have some factual inaccuracies.	Student's statements are factually correct, but do not always support their argument well.	Student's statements are factually correct and support their argument well.
Argumentative speaking and writing	Student does not present an argument that supports their position and is not supported by evidence.	Student presents an argument that does not support their position well, or is not supported by evidence.	Student presents a thoughtful argument in support of their position. Argument is supported by some evidence	Student presents a thoughtful and compelling argument in support of their position. Argument is well supported by evidence.
Alignment to role	Student's position and argument is not at all aligned with their role	Student's position and argument is not well aligned with their role	Student's position and argument is mostly aligned well with their role.	Student's position and argument is aligned well with their role.
Answering questions	Student cannot answer questions about their argument.	Student struggles to answer questions about their argument.	Student is able to answer questions about their argument.	Student is able to answer questions about their argument, and use evidence to support their answers.
Craftsmanship	Student's statement has numerous grammatical errors, and is not delivered smoothly.	Student's statement has some grammatical errors, and may not be delivered smoothly.	Student's statement is well-written, with few grammatical errors. Their presentation may not be delivered smoothly.	Student's statement is very well-written, with few or no grammatical errors. Their presentation is delivered well.

Stakeholder cards

Product Manufacturer Works for a manufacturing company that ships all of its products out using diesel trucks. Sometimes those trucks travel through residential neighborhoods to get to his customers. Has two kids and is concerned about their health from any air pollution	Student Teenager with asthma who lives near a major highway. Concerned about the health effects from air pollution on her ability to play outside and walk through her community.
Truck Driver Owns his own diesel-powered truck that he uses for his job. Knows that he will not have enough money to switch his truck to another fuel like hydrogen, or to battery power.	Mayor of Metro City Knows that a lot of the businesses in Metro City rely on diesel trucks to get products to sell, and to send out products they make. Knows that a lot of the residents of Metro City care about the environment and having clean air to breathe.
CEO of Truckville Shipping Company Runs a very large fleet of diesel trucks. Knows it will cost a lot of money to switch all of their trucks from diesel to another fuel like hydrogen, or to battery power.	Citizen scientist in Metro City Used EJ Screen and learned that particulate matter is especially high in her neighborhood, which is next to the highway Cares about environmental justice for herself and her neighbors.
Pleasant County Council member Wants Amazon to build a new warehouse in the County. Knows that Amazon currently uses a lot of diesel trucks to ship its products around the country.	Pleasant County Council member Cares about the environment of Pleasant County and is concerned about how air pollution from the trucks is already affecting the county

Health Researcher Can provide information about the health effects of air pollution on children, adults, and the elderly Cares about providing information more than siding with one opinion	Environmental scientist Can provide information about the environmental effects of air pollution Cares about providing information more than siding with one opinion
State committee member Cares about protecting the state environment Cares about protecting the health of state residents Cares about the helping trucking companies do business in the state because it provides jobs for residents and taxes for the state.	Concerned citizen Orders a lot of things online, including groceries, clothes, and cleaning supplies. Is worried that if the cost of shipping goes up, the cost of all the products will also go up to cover the extra shipping cost.

2.0 MULTIMODAL GOODS MOVEMENT NETWORK

Businesses in Maryland generate products that are shipped throughout the world while simultaneously demanding goods that are produced across the globe and shipped to Maryland. Domestic and international goods move through the Port of Baltimore or other seaports in the US, BWI/Marshall Airport or other airports in the US, and by truck or rail. Maryland's goods movement transportation network is composed of the State's highway network, freight rail network, air cargo airports, waterways, seaports, and intelligent transportation systems.

Logistics networks often span thousands of miles over land, sea, and air, and require critical multimodal connections. At a state level, Maryland's logistics network includes freight shippers and receivers, freight handling facilities, waterborne freight terminals, and air cargo facilities. The highway and rail networks provide vital connections between generating, receiving, and handling facilities.

Maryland's goods movement transportation network is comprised of 32,372 public road miles, 758 rail miles, 530 inland waterway miles, and over 50,000 feet of air cargo runways. Together, these modes moved nearly 631 million tons of freight worth $835 billion, in 2012, the most recent year of available data. By 2040, more than 1 billion tons of freight worth close to $1.6 trillion, is expected to move within and through Maryland. This section describes the components of each of these networks, including the locations of key links and nodes along with an overview of performance indicators.

Table 1: Percent of Shipments by Domestic Mode, 2012 Weight and Value

Mode	Total	Within Maryland	From Maryland	To Maryland	Through Maryland
Truck Tonnage	83.9%	96.4%	92.0%	56.7%	84.6%
Truck Value	97.7%	97.9%	93.7%	94.4%	99.3%
Rail Tonnage	12.8%	0.5%	5.1%	42.2%	11.1%
Rail Value	0.9%	<0.5%	0.7%	3.2%	0.5%
Domestic Water Tonnage*	<0.5%	<0.5%	<0.5%	<0.5%	0.0%
*Domestic Water Value**	<0.5%	<0.5%	<0.5%	<0.5%	0.0%
Domestic Air Tonnage**	<0.5%	<0.5%	<0.5%	<0.5%	0.0%
*Domestic Air Value***	0.5%	<0.5%	2.0%	1.5%	0.0%

*Domestic water Includes shallow draft, deep draft, Great Lakes, and intra-port shipments, but does not include international waterborne trade through the Port of Baltimore. The domestic (landside) moves of Port of Baltimore trade are accounted for in other modes.

**Domestic air includes air cargo between U.S. and domestic origin-destination pairs. The domestic portions of international air cargo movements are accounted for in the appropriate domestic modes.

Source: Maryland 2015 Strategic Goods Movement Plan:
http://www.mdot.maryland.gov/newMDOT/Freight/Documents/Strategic%20Goods%20Movement%20Plan.pdf

STUDENT GUIDE

Name ______________________________

Cast Your Vote!

Now that you have heard arguments for and against banning diesel trucks from traveling through residential neighborhoods, it is time for you to cast your vote. Imagine YOU were on the government committee making the decision. You will need to provide evidence supporting why you voted one way or another.

Your statement should use evidence from the committee meeting and the rest of this investigation to support your decision. Your evidence should include:

- What particulate matter is and how it affects the human body
- Where particulate matter comes from, including why it comes from diesel trucks
- Any additional details required to support your argument for or against banning diesel trucks from traveling through residential neighborhoods

My vote (circle one): FOR the ban AGAINST the ban

My statement:

Student Name ______________________________________

Diesel Truck Ban Final Vote Rubric

Project area	Beginning	Needs Improvement	Proficient	Advanced
Factual accuracy and completeness	Student's statement has several factual errors or is missing most relevant details about what particulate matter is, how it affects the human body, and how it relates to diesel trucks.	Student's statement has some factual errors and includes some relevant details about what particulate matter is, how it affects the human body, and how it relates to diesel trucks.	Student's statement is factually correct and includes most relevant details about what particulate matter is, how it affects the human body, and how it relates to diesel trucks.	Student's statement is factually correct and includes all relevant details about what particulate matter is, how it affects the human body, and how it relates to diesel trucks.
Argumentative writing	Student does not present an argument that supports their position and is not supported by evidence.	Student presents an argument that does not support their position well, or is not supported by evidence.	Student presents a thoughtful argument in support of their position. Argument is supported by some evidence	Student presents a thoughtful and compelling argument in support of their position. Argument is well supported by evidence.
Craftsmanship	Student's statement has numerous grammatical errors, and is not delivered smoothly.	Student's statement has some grammatical errors, and may not be delivered smoothly.	Student's statement is well-written, with few grammatical errors. Their presentation may not be delivered smoothly.	Student's statement is very well-written, with few or no grammatical errors. Their presentation is delivered well.

Doing Our Part

- Find ways to use less electricity: turn off electronics when you're not using them like TVs and game consoles. Turn off the lights when you leave a room or when you leave the house.

- Buy local products that were made in the United States so there is less transportation. This is especially true of food. Food that is "in season" can usually be grown from nearby states so there is less transportation involved.

- Talk to your school leaders about creating an idle-free zone at the bus and car drop off. This means that cars and buses must turn off their engines when they stop to pick up and drop off students.

- Look up anti-idling campaigns in your area of other ideas on how to prevent particulate matter pollution from idling vehicles. For example, check out Idle Free Maryland: https://mde.maryland.gov/programs/Air/MobileSources/idlefreeMD/Pages/index.aspx

- Look up the local particulate matter air quality (AQI) using a computer or install an air quality app on your phone or your parents' phone. Use the AQI so you know when and how to avoid air pollution, especially on bad days.

- Avoid places where you know the air quality is likely to be bad, such as near roadways with lots of traffic (especially big trucks) or near power, cement, and chemical plants that are in your neighborhood. When walking to school, choose a route that stays away from busy streets.

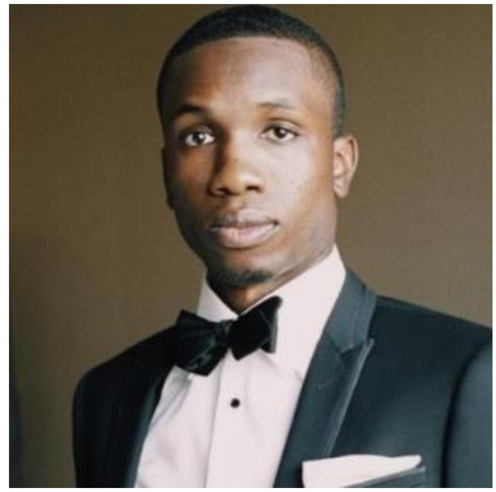
- If you sometimes have difficulty breathing, talk to your parent(s) or doctor so they can make sure you get the help you need.

About this section

This section in included in every module either as a list or as part of an activity. It describes actions students can take to mitigate the effects of air pollution in their lives, and to help prevent air pollution from getting into the atmosphere. Many of these suggestions are the same from module to module, but there are variations depending on the focus of the module.

While the actions from this section are not explicitly built into the curriculum, they can be used in various ways to motivate students and provide them opportunities to take action to make a difference in their community. For more information, see the "Doing Our Part" section in "How to Use this Curriculum"

Air Quality Champion in Our Community



Name: Joshua Shodeinde
Title: Regulatory and Compliance Engineer
Organization: Maryland Department of the Environment

How does your work relate to air quality?
I work in the Air Regulations Development Division at the Maryland Department of the Environment (MDE). MDE's mission is to protect and restore the environment for the health and well-being of all Marylanders. I work with a team of engineers who write air regulations (rules) that air pollution sources such as power plants or manufacturing facilities have to follow. These rules help to ensure that the air we breathe in Maryland is healthy and safe.

My daily tasks vary from day-to-day. One day I may share ideas with other regulators on rules to reduce pollution, on another day I may meet with businesses to help them understand a regulation. Sometimes, I read and learn about sources of air pollution and what needs to happen to improve air quality. I really enjoy the variety of my job.

What motivates you to come to work every day?
My biggest motivation is knowing that my work is directly involved with improving air quality. I used to have asthma growing up, so working in a field where I can help reduce toxic air pollutants and potentially reduce asthma attacks has a personal connection to me. I also have a young daughter who I want to grow up strong and healthy. I want her to have a love for nature and outdoor activities like taking walks or biking or hiking. Working to protect Maryland's air quality will allow my family and millions of others in the state to enjoy the great outdoors without worry.

What education and career path did you pursue to have the position that you have today?
I graduated college with a Bachelor of Science degree in Chemical Engineering. My first real job was working at a nonprofit organization, whose mission is to strengthen Baltimore's communities through education, skills development, and community service. This job taught me the importance of environmental and energy stewardship, a fancy way of saying that we should all act responsibly to protect Maryland's air, land, water, and energy. We can do this by turning off lights when we don't need them; riding our bikes and using public transportation whenever possible; not wasting water and food; and recycling. My role was to educate Baltimore residents about energy conservation and provide them with energy-saving items. Next, I worked at a company that helps business owners to upgrade their lighting to energy-efficient lights. Then I came to work at MDE.

What is your workspace like?
I work in an office cubicle, which has a table, file cabinets, and a desktop computer. I have pictures of my wife, daughter, and former colleagues in my cube. I enjoy going on walks with colleagues during break time (there's a park right beside our building) or talking about shows in the break room.
What accomplishment are you most proud of?

For work, I would say my biggest accomplishment has been writing two regulations which aim to reduce greenhouse gas emissions. It was a lot of work that required coordination with other staff at MDE, businesses, environmental advocacy groups, and concerned citizens. I remember the day I had to give a 3-hour presentation, with a question and answer session, on why these greenhouse gas regulations are important. With the help of my bosses and colleagues, we received support from everyone to move ahead with the regulations.

For my personal life, it is raising a 2-year-old. Kids are also lot of work! But I love her dearly and seeing her grow is so rewarding.

Is there something important that you want to share that we haven't asked?
I would just add that you don't need to work for an environmental agency to fight against air pollution and fight for improving air quality. Every day there is opportunity to play our role to help protect, preserve, and restore the environment. Play your part!

Glossary

air toxics - pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental and ecological effects. Also known as toxic air pollutants or hazardous air pollutants

AQI (Air Quality Index) – a scale for reporting daily air quality. The AQI tells you how clean or polluted the air is in a given location, and what the associated health risks are. The AQI focuses on health effects you may experience within a few hours or days after breathing polluted air.

arsenic – an element that occurs naturally in Earth's crust, and is commonly found in water, air, and soil. In high enough quantities or in the case of long-term exposure, arsenic can cause significant health problems

cadmium – an element that occurs naturally in Earth's crust. Cadmium can be released to the air as a result of industrial processes. Inhaling cadmium fumes can be highly hazardous to health.

cardiovascular disease – a health condition that involves narrowed or blocked blood vessels that can lead to a heart attack, chest pain, or stroke.

combustion – the chemical process of burning. Combustion requires a fuel that is burned using oxygen in a chemical reaction that produces carbon dioxide and water. See also incomplete combustion

COPD (chronic obstructive pulmonary disease) - a group of related diseases that cause airflow blockage and breathing-related problems. COPD includes emphysema and chronic bronchitis.

diesel – a type of fuel made from oil that is used in specialized combustion engines (diesel engines) where it is ignited through compression as opposed to a spark in more common combustion engines

environmental justice - the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, or any other personal characteristic with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.

incomplete combustion – a type of combustion that takes place when the supply of oxygen is poor. This results in a higher proportion of carbon monoxide gas and solid carbon (soot) being produced instead of carbon dioxide. Water is still a product of incomplete combustion.

lung function – a term used to describe how well the lungs work in helping a person breathe. Lungs function is measured by lung size, air flow, and other aspects of lung health.

micrometer/micron (symbol: μ) – a unit of length equal to one-millionth of a meter (0.000001 m). Micrometer is the SI unit of measure, while micron is the former name of the unit which is still in common use.

ozone (O_3) - a natural and a man-made gas made of three oxygen atoms that occurs in the Earth's upper atmosphere (the stratosphere) and lower atmosphere (the troposphere). Depending on where it is in the atmosphere, ozone affects life on Earth in either good or bad ways.

particulate matter (abbreviation: PM) - a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Larger particles are called PM 10, smaller particles are called PM 2.5, based on their diameter in micrometers.

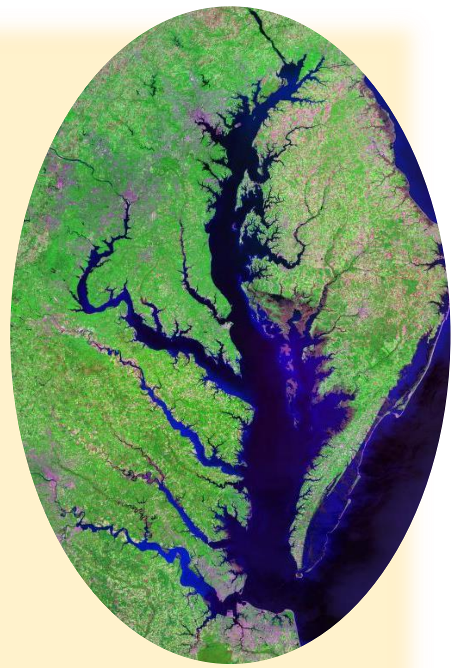
soot - a black powdery or flaky substance consisting largely of amorphous carbon, produced by the incomplete burning of organic matter including fossil fuels.

MODULE 4

Air & The Chesapeake Bay

Dead Zones, Deposition, and Nitrogen Pollution

Module Overview



The Chesapeake Bay is a natural treasure: it provides innumerable resources and ecosystem services to the living things in its watershed, especially humans. Yet the Bay is also a fragile ecosystem that has been inundated with pollution of all kinds. One of the oft-overlooked sources of pollution to the Bay is air pollution, which contributes a significant amount of nutrient pollution to its waters. In this Meaningful Watershed Educational Experience (MWEE) based module, students start by investigating a fish kill in the Bay, tracing the cause of this phenomenon back to algae blooms and nutrient pollution. Then they continue to work backwards to understand the sources of this nutrient pollution. Along the way they learn about watersheds and airsheds, and collect data on atmospheric deposition. Using this information, they build a model of pollution to the Bay, which they draw upon to create and implement an action plan to combat pollution. As a culmination of their investigation, students present their model and findings to local stakeholders.

Anchor phenomenon: A large area of dead fish floating in the Chesapeake Bay.

Pacing

- 12 activities (1 optional) including action project and presentation
- Approximately 12-13 class periods (plus 1 optional) plus time for action project and presentation (4+ class periods)

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When to Teach This Module

Finding the right place within a science scope and sequence to investigate air pollution with students can be tricky. Below you will find some information about the module that can help you decide where this it might fit into your own plans for student leaning:

- **Connection to Ecosystems**: Air pollution can have a tremendous effect on the health of ecosystems, including the Chesapeake Bay. With activities focused on algae blooms, dissoved oxygen, and modeling cause-effect relationships in the Chesapeake Bay, this module would fit well as part of an ecoystem unit, especially in connection with food webs and energy transfers.

- **Connection to Human Impacts on Earth Systems**: Because this module focuses specifically on how *pollution* affects the Chesapeake Bay, it would work well as an addition to a unit on human impacts on earth systems by exploring the mechanism of how human activities affect ecosystems.

- **Meaningful Watershed Educational Experience (MWEE):** This module fulfills a component of the Cheseapeake Bay Agreement that all students in 6-8th grades experience a Meaningful Watershed Eductational Experience. To learn more about MWEEs, see the Teacher Background Information section below.

Timing Notes

The timing for this module can be tricky due to a few specific activities. Keep the following things in mind when planning out the schedule for the module:

- Activity 3 (Algae in a Bottle) is an experiment that runs for two weeks. There are a few different options for when to run the experiment that are noted in the activity itself. The activity also works well during a time when students will be in and out of normal class (ex. during holidays, testing, etc.), as long as they have intermittent times to check in with their results.

- Activity 11 (Measuring Wet Deposition of Nitrogen) requires rainwater. You can adjust when to lead this activity based on when it rains, or you can collect and freeze rainwater. See the activity itself for details.

- Activity 12 (Doing our Part) is a action project that requires some advance planning and additional time and resources to complete. Make sure to plan well enough ahead, and to provide enough class time to complete the project.

- Activity 13 (Presenting the Chesapeake Bay) is based on student presentations that will require some advance planning time and class time to complete, especially if you want students to present for an authentic audience.

Standards Overview

Middle School NGSS standards alignment:

Performance Expectations

Focus PE:

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.]

Science & Engineering Practices

Focus SEP: Constructing explanations and designing solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.
- Construct an explanation using models or representations.
- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
- Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.

Background SEP: Developing & Using Models

Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

- Develop and/or use a model to predict and/or describe phenomena.
- Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

Background SEP: Planning and carrying out investigations

Planning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions.

- Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
- Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.

Disciplinary Core Ideas

Focus DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience

Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

Background DCI: ESS3.C: Human Impacts on Earth Systems

Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.

Crosscutting Concepts

Focus CCC: Cause and Effect: Mechanism and Prediction – Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Background CCC: Systems and System Models – A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

- Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.
- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

NGSS 5th Grade Standards alignment

Performance Expectations:

Focus SEP: 5-ESS2-1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. [Clarification Statement: Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere. The geosphere, hydrosphere, atmosphere, and biosphere are each a system.] [Assessment Boundary: Assessment is limited to the interactions of two systems at a time.]

Background SEP: 5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

Science & Engineering Practices

Focus SEP: Constructing explanations and designing solutions
The goal of *science* is the construction of theories that provide explanatory accounts of the material world.
The goal of *engineering* design is a systematic approach to solving engineering problems that is based on scientific knowledge and models of the material world.

Background SEP: Developing & Using Models
Science often involves the construction and use of models and simulations to help develop explanations about natural phenomena.
Engineering makes use of models and simulations to analyze systems to identify flaws that might occur or to test possible solutions to a new problem.

Background SEP: Planning and carrying out investigations
A major practice of *scientists* is planning and carrying out systematic scientific investigations that require identifying variables and clarifying what counts as data.
Engineering investigations are conducted to gain data essential for specifying criteria or parameters and to test proposed designs.

Disciplinary Core Ideas

Focus DCI: ESS3.C: Human Impacts on Earth Systems
Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. (5-ESS3-1)

Background DCI: ESS2.A: Earth Materials and Systems
Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. (5-ESS2-1)

Crosscutting Concepts

Focus CCC: Cause and Effect: Mechanism and Prediction – Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain new contexts.

Background CCC: Systems and System Models – Defining the system under study – specifying its boundaries and making explicit a model of that system – provides tools for understanding and testing ideas that are applicable throughout science and engineering.

Virginia Standards of Learning (SOLs) alignment

Science & Engineering Practices	
5.1 (b)	Planning and carrying out investigations. The student will… • collaboratively plan and conduct investigations to produce data • take metric measurements using appropriate tools
5.1 (d)	Constructing and critiquing conclusions and explanations. The student will… • construct and/or support arguments with evidence, data, and/or a model
5.1 (e)	Developing and using models. The student will… • develop models using an analogy, example, or abstract representation to describe a scientific principle or design solution
6.1 (b)	Planning and carrying out investigations. The student will… • independently and collaboratively plan and conduct observational and experimental investigations; identify variables, constants, and controls where appropriate, and include the safe use of chemicals and equipment • take metric measurements using appropriate tools
6.1 (d)	Constructing and critiquing conclusions and explanations. The student will… • construct scientific explanations based on valid and reliable evidence obtained from sources (including the students' own investigations)
6.1 (e)	Developing and using models. The student will… • use, develop, and revise models to predict and explain phenomena
Content Standards	
6th Grade 6.8	The student will investigate and understand that land and water have roles in watershed systems. Key ideas include: a) a watershed is composed of the land that drains into a body of water; c) the Chesapeake Bay is an estuary that has many important functions; d) natural processes, human activities, and biotic and abiotic factors influence the health of a watershed system.
Life Science LS.8	The student will investigate and understand that ecosystems, communities, populations, and organisms are dynamic and change over time. Key ideas include: b) changes in the environment may increase or decrease population size; c) large-scale changes such as eutrophication, climate changes, and catastrophic disturbances affect ecosystems.
Life Science LS.9	The student will investigate and understand that relationships exist between ecosystem dynamics and human activity. Key ideas include: b) changes in habitat can disturb populations; c) variations in biotic and abiotic factors can change ecosystems.
Biology BIO.8	The student will investigate and understand that there are dynamic equilibria within populations, communities, and ecosystems. Key ideas include: d) natural events and human activities influence local and global ecosystems and may affect the flora and fauna of Virginia.
Earth Science ES.11	The student will investigate and understand that the atmosphere is a complex, dynamic system and is subject to long-and short-term variations. Key ideas include d) human actions, including economic and policy decisions, affect the atmosphere.

Common Core State Standards alignment

Literacy Standards	
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
RST.6-8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
WHST.6-8.1	Write arguments focused on discipline-specific content.
WHST.6-8.1B	Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources.
WHST.6-8.9	Draw evidence from informational texts to support analysis, reflection, and research.
SL.8.5	Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest
SL.8.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.
SL.8.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.
Math Standards	
6.SP.B.5	Summarize numerical data sets in relation to their context

5E Module Flow

Activity 1 (Engage): The Dead Zone
Timing: 30 minutes
Purpose: Introducing the anchor phenomenon
- ✓ Students will make observations of the anchor phenomenon
- ✓ Students will ask questions to better define the anchor phenomenon
- ✓ Students will develop preliminary hypotheses about what causes dead zones

Activity 2 (Explore): Introducing the Chesapeake Bay
Timing: 45 minutes
Purpose: Building background knowledge about the Chesapeake Bay and developing questions about it.
- ✓ Students will know key information about the Chesapeake Bay
- ✓ Students will develop questions about the Chesapeake Bay

Activity 3 (Explore/Explain): Algae in a Bottle
Timing: 2 class periods + intermittent time to collect data
Purpose: Performing an experiment to show how nutrient pollution affects algae growth
- ✓ Students will perform an experiment to determine the effects of excess nitrogen in natural bodies of water
- ✓ Students will understand that eutrophication, nutrient pollution (specifically nitrogen), and dead zones are all connected

Activity 4 (Explain): Algae: The Silent Killer
Timing: 60 minutes
Purpose: Using real-world data to show the connection between algae blooms, low dissolved oxygen levels, and dead zones
- ✓ Students will interpret a graph and read a text to learn how algal blooms result in dead zones.

Activity 5 (Explain): Where is the Pollution Coming From?
Timing: 30 minutes
Purpose: Identifying the major sources of nitrogen pollution to the Chesapeake Bay
- ✓ Students will be able to name the primary sources of nitrogen pollution to the Chesapeake Bay

Activity 6 (Explore/Explain): Rain, Pollution, and Watersheds
Timing: 45 minutes
Purpose: Building background knowledge about watersheds, and how they transfer pollution to the Chesapeake Bay
- ✓ Students will be able to define watershed, geosphere, and hydrosphere, and explain how they connect
- ✓ Students will be able to describe how land-based nutrient pollution gets into the Chesapeake Bay
- ✓ Students will know that some pollution gets into the Bay when it washes off the land

Activity 7 (Explore): How Do Gases Get Into Liquids? (optional)
Timing: 30-45 minutes
Purpose: Understanding the concept of dissolving in order to understand how oxygen can be dissolved in water and air pollution can be dissolved in rainwater
- ✓ Students will understand the concept of a gas dissolved in a liquid
- ✓ Students will understand that "polluted rain" can have a significant effect on objects

Activity 8 (Explain): Air Pollution in the Chesapeake Bay
Timing: 45 minutes
Purpose: Understanding different ways air pollution can get into a body of water like the Chesapeake Bay, and where that air pollution comes from
- ✓ Students will be able to describe how air pollution gets into the Chesapeake Bay
- ✓ Students will know the definition of airshed
- ✓ Students will know the term "deposition"

Activity 9 (Explain): Modeling Pollution in the Chesapeake Bay
Timing: 45 minutes
Purpose: Using modeling to put together all the pieces of what students have learned thus far
- ✓ Students will begin to create a model of how pollution enters the Chesapeake Bay

Activity 10 (Explain): What's Going on in our Airshed?
Timing: 45 minutes
Purpose: Learning the sources of nitrogen pollution in the Chesapeake Bay airshed
- ✓ Students will identify major sources of pollution in the airshed

Activity 11 (Explore): Measuring Wet Deposition of Nitrogen
Timing: 2-3 class periods
Purpose: Conducting an experiment to determine if rainwater in the school community has been polluted with nitrogen
- ✓ Students will collect and analyze data to determine if rainwater in the school community is polluted with nitrogen

Activity 12 (Elaborate): Doing Our Part
Timing: variable
Purpose: Providing students a way to make a positive change for the Chesapeake Bay ecosystem
- ✓ Students will plan and implement an action project to decrease pollution inputs into the Chesapeake Bay

Activity 13 (Evaluate): Presenting the Chesapeake Bay
Timing: variable
Purpose: Demostrating student learning by presenting to an authentic audience
- ✓ Students will use their models and research to create a presentation of the problem of nitrogen pollution in the Chesapeake Bay.

Module Materials

Activity 1 (Engage): The Dead Zone

- ❒ Handouts: Phenomenon Observations, Hypotheses, and Questions
- ❒ Materials needed: "Clues" board with sentence strip about the dead fish
- ❒ Optional materials: none

Activity 2 (Explore): Introducing the Chesapeake Bay

- ❒ Handouts: I see & hear, I think, I wonder: The Chesapeake Bay (with teacher guide), About the Chesapeake Bay reading
- ❒ Materials needed: Projector & speakers, Chart paper (or other way to display document)
- ❒ Optional materials: none

Activity 3 (Explore/Explain): Algae in a Bottle

- ❒ Handouts: Algae in a Bottle experiment procedure, Data collection sheet, Analysis & summary sheet
- ❒ Materials needed: Materials for Algae in a Jar experiment (see below), Dissolved oxygen test kit, Additional glassware (ex test tubes) so multiple students can test at the same time, For clues board: "Lots of algae in the Bay before fish died", Algae in a Bottle Teacher Guide
- ❒ Optional materials: none

Activity 4 (Explain): Algae: The Silent Killer

- ❒ Handouts: Reading: Algae & Dissolved Oxygen (double-entry journal)
- ❒ Materials needed: Computer & projector, Word wall words: dissolved oxygen, algae, algae bloom, decomposer
- ❒ Optional materials: none

Activity 5 (Explain): Where is the Pollution Coming From?

- ❒ Handouts: Where is the Pollution Coming From?
- ❒ Materials needed: Computer & projector
- ❒ Optional materials: none

Activity 6 (Explore/Explain): Rain, Pollution, and Watersheds

- ❒ Handouts: Watershed Notes sheet
- ❒ Materials needed: Plain paper (enough for all students, Spray bottle(s) with water (one or more), Water-soluble markers (see below for more details) – enough for all students, Paper towels for cleanup, Crumpled Paper Watershed teacher guide, Word wall words: watershed, geosphere, hydrosphere, Computer & projector
- ❒ Optional materials: none

Activity 7 (Explore): How do Gases Get Into Liquids? (optional)

- ❒ Handouts: Disappearing salt
- ❒ Materials needed: Salt, Cups of water, Stirrers, Bottle of carbonated beverage (ex. soda), Word wall words: dissolve
- ❒ Optional materials: none

Activity 8 (Explain): Air Pollution in the Chesapeake Bay

- ❒ Handouts: Welcome to the Airshed
- ❒ Materials needed: Word wall words: airshed, dry deposition, wet deposition; Blank paper (enough for all students); Spray bottle(s) with water (one or more); Chocolate pudding mix in small cups; Cotton balls; Water in small cups
- ❒ Optional materials: none

Activity 9 (Explain): Modeling Pollution in the Chesapeake Bay

- ❒ Handouts: none
- ❒ Materials needed: Computer & projector, Pre-printed/written parts of the Chesapeake Bay pollution model (these can be on paper or on sentence strips) including lots of arrows, Extra paper and markers to add components to the model
- ❒ Optional materials: none

Activity 10 (Explain): What's Going on in our Airshed?

- ❒ Handouts: Nitrogen Air Pollution
- ❒ Materials needed: Computer & projector, Animated nitrate maps (downloaded from http://nadp.slh.wisc.edu/maplib/ani/no3_conc_ani.pdf), Animated ammonium maps (downloaded from http://nadp.slh.wisc.edu/maplib/ani/nh4_conc_ani.pdf), Sentence strips for Chesapeake Bay pollution model: nitrate, ammonium, power plants, agriculture, cars, trucks, etc.
- ❒ Optional materials: none

Activity 11 (Explore): Measuring Wet Deposition of Nitrogen

- ❒ Handouts: Nitrogen Deposition in Rainwater
- ❒ Materials needed: Nitrate and ammonia test kits (see note on materials), Additional glassware (ex. small beakers) to allow for multiple groups to test at the same time if necessary, Rainwater collectors (ex. jars), Distilled water (to use as a control), Safety & cleanup materials (safety goggles, paper towels, etc.), Tips for Measuring Nitrogen Deposition in Rainwater (teacher guide)
- ❒ Optional materials: none

Activity 12 (Elaborate): Doing Our Part

- ❒ Handouts: none
- ❒ Materials needed: Vary depending upon project chosen
- ❒ Optional materials: none

Activity 13 (Evaluate): Presenting the Chesapeake Bay

- ❒ Handouts: Student Presentation Rubric
- ❒ Materials needed: Student Presentation Planning Guide
- ❒ Optional materials: vary depending upon presentation type(s) chosen

Cost considerations

Unlike most of the other On the Air activities, this module contains a few different activities that have more significant costs. Algae in A Bottle (Activity 3) can be done with several recyclable materials, but it also requires fertilizer and a dissolved oxygen test kit. Measuring Wet Deposition of Nitrogen (Activity 11) requires at least one test kit for nitrate and/or ammonium. In addition, the action project (Activity 12) may require additional materials depending on what you and your students choose to do.

Below are a few suggestions to help manage some of these costs if they are a concern:

- **Create a Donors Choose page with the required materials.** Everything that is needed for the module can be purchased online, so creating a way for donors to provide the materials can be very straightforward.

- **Ask for donations from local stores**. The dissolved oxygen test kit (Activity 3) is sold at most pet stores and aquarium shops. The fertilizer (Activity 3) can be found at many garden stores or nurseries (just make sure to get the proper fertilizers). Materials for action projects (Activity 12) can often be found at local retailers.

- **Reach out to local environmental organizations**. There are many local branches of groups such as The Sierra Club and the Audubon Society who may be willing to provide funding for small projects such as this.

- **Apply for a mini-grant.** In the past, the Chesapeake Bay Trust (CBT) has offered small grants (up to $5,000) for schools to conduct MWEEs. Other organizations offer similar grants. The CBT MWEE grant page is here: https://cbtrust.org/grants/environmental-education-mini/ and Bay Baypack's funding page which lists lots of similar funding opportunities is here: http://baybackpack.com/funding

What is a MWEE?

This module is designed as a MWEE or Meaningful Watershed Educational Experience, as defined by the Chesapeake Bay Watershed Agreement. Students in Maryland, DC, and Virginia are expected to complete at least one MWEE during their middle school education.

If you are new to MWEEs, the information below will help you understand why certain elements of the module are written as they are. There are lots of MWEE resources available online which you may find helpful to access during the module, especially towards the end during the student presentation and action project activities. Links to a few of these resources are below.

The following information comes from the Chesapeake Bay Program's "An Educator's Guide to the Meaningful Watershed Educational Experience"

What is a MWEE?
MWEEs are learner-centered experiences that focus on investigations into local environmental issues that lead to informed action and civic engagement. Both teachers and students play important roles in the MWEE by working together in partnership. Teachers present unbiased information and assist students with their research and exploration, while students go through the inquiry process and ultimately take action to address the issue. Four essential elements and four supporting practices build upon each other to create this comprehensive learning experience for students

What are the parts of a MWEE?
The MWEE consists of four essential elements that describe "what students do." These elements promote a learner-centered approach that emphasizes the role of the student in actively constructing meaning from the learning experiences. Throughout the process students have time for reflection, allowing them to refocus on how what they are learning and experiencing affects the driving question of their investigations. The four elements are Issue Definition, Outdoor Field Experiences, Synthesis & Conclusions, and Stewardship & Civic Action.

To learn more about MWEEs, check out these resources:

- An Educator's Guide to the Meaningful Watershed Educational Experience: https://www.cbf.org/document-library/education/teachers-guide-to-meaningful-watershed-education-experience.pdf. This is the definitive guide to MWEEs

- Bay Backpack: http://baybackpack.com/. This website has innumerable resources for learning more about MWEEs, as well as ideas for creating action projects, teaching resources centered on the Chesapeake Bay, field studies, and funding ideas

- The National Oceanic and Atmospheric Administration (NOAA) supports MWEEs through grants and training experiences. Check out their MWEE website at: https://www.noaa.gov/education/explainers/noaa-meaningful-watershed-educational-experience

- The Chesapeake Bay Foundation is one the largest supporters of MWEEs in the area through training and field experiences. Check out their MWEE page, which includes links for trainings, field experiences, and resources here: https://www.cbf.org/join-us/education-program/mwee/

Teacher Background Information

Nutrient Pollution

Nutrient pollution is one of America's most widespread, costly and challenging environmental problems, and is caused by excess nitrogen and phosphorus in the air and water.

Too much nitrogen and phosphorus in the water can have diverse and far-reaching impacts on public health, the environment and the economy. Photo credit: Bill Yates

Nitrogen and phosphorus are nutrients that are natural parts of aquatic ecosystems. Nitrogen is also the most abundant element in the air we breathe. Nitrogen and phosphorus support the growth of algae and aquatic plants, which provide food and habitat for fish, shellfish and smaller organisms that live in water.

But when too much nitrogen and phosphorus enter the environment - usually from a wide range of human activities - the air and water can become polluted. Nutrient pollution has impacted many streams, rivers, lakes, bays and coastal waters for the past several decades, resulting in serious environmental and human health issues, and impacting the economy.

Excess nitrogen in the air can impair our ability to breathe, limit visibility and alter plant growth.

Too much nitrogen and phosphorus in the water causes algae to grow faster than ecosystems can handle. Significant increases in algae harm water quality, food resources and habitats, and decrease the oxygen that fish and other aquatic life need to survive. Large growths of algae are called algal blooms and they can severely reduce or eliminate oxygen in the water, leading to illnesses in fish and the death of large numbers of fish. Some algal blooms are harmful to humans because they produce elevated toxins and bacterial growth that can make people sick if they come into contact with polluted water, consume tainted fish or shellfish, or drink contaminated water.

Nutrient pollution in ground water - which millions of people in the United States use as their drinking water source - can be harmful, even at low levels. Infants are vulnerable to a nitrogen-based compound called nitrates in drinking water. Excess nitrogen in the atmosphere can produce pollutants such as ammonia and ozone, which can impair our ability to breathe, limit visibility and alter plant growth. When excess nitrogen comes back to earth from the atmosphere, it can harm the health of forests, soils and waterways.

Source: Nutrient Pollution, US EPA, https://www.epa.gov/nutrientpollution

Nitrogen Dioxide Basics

What is NO_2 and how does it get in the air?

Nitrogen Dioxide (NO_2) is one of a group of highly reactive gases known as oxides of nitrogen or nitrogen oxides (NO_x). Other nitrogen oxides include nitrous acid and nitric acid. NO_2 is used as the indicator for the larger group of nitrogen oxides.

NO_2 primarily gets in the air from the burning of fuel. NO_2 forms from emissions from cars, trucks and buses, power plants, and off-road equipment.

Effects of NO_2

Health effects

Breathing air with a high concentration of NO_2 can irritate airways in the human respiratory system. Such exposures over short periods can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions and visits to emergency rooms. Longer exposures to elevated concentrations of NO_2 may contribute to the development of asthma and potentially increase susceptibility to respiratory infections. People with asthma, as well as children and the elderly are generally at greater risk for the health effects of NO_2.

NO_2 along with other NO_x reacts with other chemicals in the air to form both particulate matter and ozone. Both of these are also harmful when inhaled due to effects on the respiratory system.

Environmental effects

NO_2 and other NO_x interact with water, oxygen and other chemicals in the atmosphere to form acid rain. Acid rain harms sensitive ecosystems such as lakes and forests.

The nitrate particles that result from NO_x make the air hazy and difficult to see though. This affects the many national parks that we visit for the view.

NO_x in the atmosphere contributes to nutrient pollution in coastal waters.

Source: Basic Information About NO_2, US EPA, https://www.epa.gov/no2-pollution/basic-information-about-no2#What%20is%20NO2

Additional Information

Nutrient Pollution

- The EPA website on nutrient pollution has excellent information about sources and solutions, effects, action projects at home and in the community, and policy information. Access the main nutrient pollution site at: https://www.epa.gov/nutrientpollution for links to all this information

Air Pollution and the Chesapeake Bay

- The Chesapeake Bay Foundation's Interactive Slideshow "The Unseen Traveler" has excellent information on how air pollution from specific sources affects the Chesapeake Bay. Access the slideshow at: https://www.cbf.org/issues/air-pollution/the-unseen-traveler.html

Dead Zones, Dissolved Oxygen, and Nutrient Pollution

- Chesapeake Bay Dead Zones (animated) https://www.youtube.com/watch?v=zJ4l0fDq3MI

NOx in the News

- The Volkswagen diesel emissions scandal allowed cars to emit more than 40 times the legal limit of nitrogen dioxide into the air. Learn more about the scandal from BBC new here: https://www.bbc.com/news/business-34324772

Activity 1 (Engage): The Dead Zone

ACTIVITY DETAILS

Time: 30 minutes

Objectives
- ✓ Students will make observations of the anchor phenomenon
- ✓ Students will ask questions to better define the anchor phenomenon
- ✓ Students will develop preliminary hypotheses about what causes dead zones

Materials
- ✓ "Clues" board with sentence strip about the dead fish

Handouts
- ✓ Phenomenon Observations, Hypotheses, and Questions

Activity summary: In this introductory activity, students are introduced to the phenomenon of fish kills in the Chesapeake Bay by looking at photographs. They make observations of the fish in order to develop hypotheses and research questions that will guide the rest of the investigation.

Standards Connection
DCI: LS2.C: Ecosystem Dynamics, Functioning & Resilience
SEP: Asking Questions and Defining Problems
CCC: Cause & Effect

Warmup: What do you know about fish?

- The purpose of this warmup is to prime students' thinking about what fish need to live to help them better come up with questions and hypotheses about what caused the fish kill in the Chesapeake Bay.

1. **Frame the activity:** Tell students that today they are beginning a new investigation. For this investigation, they are going to be investigating a (murder) mystery to see if they can figure out whodunit.

2. **Introduce the Phenomenon:** Show students either a dead fish (from the grocery store) or a picture of one like this:

Hand out the phenomenon observations sheet, and have students write down observations. For example:

- The fish is on the sand (not in the water)
- The scales are silver
- The fish's eye seems to be missing

Next, show students a picture of a big group of dead fish in the water like one of these and tell them that these pictures come from the Chesapeake Bay:


Have students make more observations in the second row on their observations sheet. Key noticings:

- There are a lot of the same kind of fish
- There doesn't appear to be a net or a fishing line
- The fish have colors that make them look unhealthy

3. **Develop hypotheses:** Ask students what they think **caused** these fish to die. Have them take a moment to jot down some ideas on their observation sheet in the middle column. Afterwards, have them share out, and make a list on the board or chart paper and save the list for future activities. If they are stuck on hypotheses, have theme think back to what they know about fish that they shared during their warmup (ex. they have gills, they eat other fish, plants, and algae, etc.).

4. **Develop questions:** Ask students what questions they need to answer to find out what killed the fish. Their questions should be related to their hypotheses. For example, if they think the fish died because it didn't have enough food, we should ask, "How much food is in the water?" and "What do fish eat?" If our hypothesis is that they were killed by a disease, our question should be "Are there any diseases that kill fish in the Chesapeake Bay?" They may also add more general questions like "What do fish need to live?" and "What is the water like in the Chesapeake Bay?" Have them write their questions the right column. After students have had a chance to write some questions, have them share out, and make a list on the board or on chart paper that you can save for future activities.

TEACHER NOTES

Teacher Tip

✓ Make sure that when students are making observations, they are not drawing conclusions. For example, if students say "the fish are dead," push them to describe what observations they made to reach that conclusion (ex. they're not moving, they're at the surface, they're floating on their sides). These observations may provide valuable clues that "the fish are dead" does not.

Modification

✓ If students are uncomfortable sharing their hypotheses or questions out loud, have them write them on sticky-notes or slips of paper and put them up on a bulletin board.

TEACHER NOTES

Optional

- ✓ Have students read the interview with the module's Air Quality Champion to get them into the frame of mind of what they'll be investigating

5. **Framing the investigation:** Tell students that for this investigation, they are going to take on the role of marine biologists to try to solve the mystery of what killed these fish. They will use clues that they gather throughout the investigation to try to solve the mystery. Point out a spot on the wall where you have posted the word "Clues". Add your first clue: dead fish in the Chesapeake Bay.

6. **Formative assessment:** Have students use what they learned during the activity to write an observation, a hypothesis, and a question that go together into a single statement. For example:
   - I saw that there were a lot of dead fish together, so I think that they were killed by poison that someone dropped in the water. My question is: is there poison in the Chesapeake Bay?

Air Quality Champion

Dr. Lewis Linker is an environmental scientist who makes models of the Chesapeake Bay. His work allows leaders to make smart plans about how to clean up the Bay and restore it to good health. Learn more about Dr. Linker and his work at the end of the module.

Name ______________________________

STUDENT HANDOUT

Phenomenon Observations, Hypotheses & Questions

Cause & Effect

What do you see?	What do you think could have caused this?	What questions do we need to answer?
One fish		
Many fish		

Activity 2 (Explore): Introducing the Chesapeake Bay

ACTIVITY DETAILS

Time: 45 minutes

Objectives

- ✓ Students will know key information about the Chesapeake Bay
- ✓ Students will develop questions about the Chesapeake Bay

Materials

- ✓ Projector & speakers
- ✓ Chart paper (or other way to display document)

Handouts

- ✓ I see & hear, I think, I wonder: The Chesapeake Bay (with teacher guide)
- ✓ About the Chesapeake Bay reading

Modification

- ✓ For the warmup, put butcher paper out on a table (or tables) and have students write whatever they know about the Chesapeake Bay on it. Have enough paper so that all students can write on it at the same time.

Activity summary: In this activity, students get to know the Chesapeake Bay a little better by watching a video, looking at maps, and reading an article. The goal is for students to develop greater familiarity and connection with the Bay, while also learning some important facts for their investigation.

<u>Standards Connection</u>

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience

A Note About Place-Based Learning

Students may have a conceptual idea of the Bay, or they may have seen it when they rode over the Bay bridge, but few of them have the strong internal connection for the Bay that many conservationists have. Be sure to help students develop some of that connection, which goes beyond the technical definition of what they Bay is. The video students watch in this activity is designed to help with that. You may also consider putting up pictures of the Bay around the classroom during this module to help students build that connection, or even scheduling a trip with organizations like CBF to take students to the Bay.

Warmup: What do you know about the Chesapeake Bay?

- This warmup is designed to provide some information on students' background knowledge about the Bay. Some students may have a lot of background knowledge, and some will likely have none. Encourage all students to write something (ex. all students should know that it has water in it). Have students share after the warmup so that others can benefit from their background knowledge. You may want to look at students' answers beforehand and ask a few students to share specific important information.

1. **Frame the activity:** Remind students that they all know different things about the Chesapeake Bay. Tell them that in order for them to solve the mystery of what killed the fish in the Bay, it would help for everyone to know a little more about the Bay. If students included questions in Activity 1 that relate to knowing more about the Bay, connect today's activity back to answering those questions.

2. **Video: The Chesapeake Bay by Air (preview).** Pass out the "I see & hear, I think, I wonder: Chesapeake Bay" sheet for students. Explain that during the video, they are going to see and hear lots of information about the Chesapeake Bay. Their job is to make notes on things that they see and hear in the top section of their handout. Afterwards they will add some things that they think and wonder. When students are ready, show the preview version of the Chesapeake Bay by Air video: https://www.youtube.com/watch?v=FpJz1wsF6Z8

3. **Video Share**: Have students turn to a partner and share some of the things they heard and saw in the video. Then have each pair share something with the whole class. Record these for the class on chart paper or in a projected document.

4. **I think:** With their partners, have students write down some things that they think they know about the Chesapeake Bay in their "I think" section. They may ask if something is true or not, and it is okay to share answers if you know them. Otherwise, you can tell them to write their idea as a question in the "I wonder" section. They can use some things they said or heard during the warmup for this section as well.

5. **Reading: About the Chesapeake Bay:** Hand out the article, *About the Chesapeake Bay*. Have students start by looking for information from the two maps and writing it in the "I see" section at the bottom of their handouts. Then have them identify key information from the reading to add to the bottom of their handout in the "I think" section. Key takeaways:
   - The Chesapeake Bay is an estuary, which means it is where freshwater from rivers and the saltwater from the ocean meet and mix together
   - The Bay has more than 3,000 species of plant and animal life
   - The Bay is relatively shallow (average depth of 21 feet)
   - The Bay is 200 miles long
   - Freshwater comes into the Bay from 50 major tributaries (rivers that flow into the bay)
   - The Bay's watershed covers 6 states and Washington D.C.
   - The Chesapeake Bay has pollution in it

6. **I wonder**. Have students write down additional questions they have about the Bay from the video or the reading in the "I wonder" section. Have them share some questions, and add them to the list of student questions from Activity 1. Make sure that at least one "I wonder" question relates to pollution in the Bay (ex. "What kind of pollution is in the Bay?" or "Where does pollution in the Bay come from?"). This will be necessary for Activity 5.

TEACHER NOTES

Modification

- ✓ Consider showing the video without sound (or show it twice, without the sound the first time). This will help students to focus on visual observations.

The Chesapeake Bay Report Card

- ✓ The student reading includes a reference to a C- grade that the Chesapeake Bay received for health. For years, the Chesapeake Bay Foundation has published a "State of the Bay" report card grading the Bay's health on a number of indicators. In 2019, the University of Maryland Center for Environmental Science (UMCES) published the most recent report card. You can access that report card here: https://ecoreportcard.org/report-cards/chesapeake-bay/

TEACHER NOTES

Word wall

✓ Add the word estuary to the word wall at the end of this lesson when you are going over the exit ticket

7. **Return to the phenomenon.** Remind students about the dead fish in the Bay from Activity 1. Ask students if anything they saw or read might be a helpful clue in figuring out what killed the fish. For example, they may have written down that the Bay is polluted. This might be a clue as to what caused the fish to die. They may also have noticed that the water is sometimes brown. Don't pass any judgment on students' suggestions, and put a star by any questions that students think may be helpful for their investigation. You can also help students develop any new questions which might help in their investigation based on the video and the reading. For example:
    - Where does the pollution in the Bay come from?
    - How does the pollution get from there into the Bay?

    Encourage students to add any important new questions to their "I wonder" section.

8. **Formative assessment** (Exit ticket)
    - What is an estuary?
    - How does freshwater get into the Chesapeake Bay?
    - How does saltwater get into the Chesapeake Bay?

STUDENT HANDOUT

Name________________________________

I See & Hear, I Think, I Wonder…

The Chesapeake Bay

Source	I See & Hear	I Think	I Wonder
Video			
Map & Reading			

TEACHER GUIDE

I See & Hear, I Think, I Wonder…

The Chesapeake Bay

Source	I See & Hear	I Think	I Wonder
Video	• Towns • Brown water • Bridges • The shoreline would stretch to the west coast and back • Potomac • James • Lighthouses • Farms • Marshes	• The Potomac is a river that goes into the Bay • The water is dirty • There is a bridge that goes over the Bay that leads to Ocean City	• How far away is the Bay from school? • Is the water really dirty? • What lives in the Bay?
Map & Reading	• The Bay is between Maryland, Delaware, and Virginia • The Bay looks like a big chicken finger • The Chesapeake Bay is long and skinny • The Chesapeake Bay is mostly north & south	• There are lots of different animals in the Bay like crabs, fish, and birds. • There are lots of plants in the Bay • The Bay is an estuary (salty and fresh water) • The Bay is mostly shallow • The Bay is very long (200 miles) • The Bay is connected to the Atlantic Ocean • Many rivers flow into the Bay • The Bay is polluted	• Can you swim in the Bay? • Can you drink the water? • Where does pollution in the Bay come from?

STUDENT HANDOUT

Name ______________________________

About the Chesapeake Bay

The Chesapeake Bay is a 200-mile-long body of water that connects many rivers in Maryland Washington D.C., and Virginia to the Atlantic Ocean. In fact, the Chesapeake Bay watershed – the area of land that drains its water into the Bay, includes 6 different states and Washington, D.C.! The Chesapeake Bay is an **estuary**, which means that it is a place where freshwater and salt water mix. More than 50 major streams and rivers flow into the Bay.

Many different living things depend on the Chesapeake Bay. More than 3,000 species of animals and numerous species of plants live in the Bay or use it for food or shelter. Blue crabs and oysters are probably the most famous animals in the Bay, but many birds, like pelicans and osprey live there too. So do rockfish, river otters, and diamondback terrapin turtles. Underwater grasses and algae are also very important parts of the Chesapeake Bay ecosystem.

The Chesapeake Bay is not very deep in most places. The average depth of the Bay is 21 feet, although the deepest point is 174 feet. However, because it is so big, the Bay can hold more than 15 trillion gallons of water.

The Chesapeake Bay is very important to humans for many reasons. 10 million people live along the shore of the Bay or nearby and use it for recreation, food, and work. We harvest more than 500 MILLION pounds of seafood from the Bay every year!

The Chesapeake Bay also has a pollution problem. In 2019, the Bay got a score of C- for its health. That means we all need to do what we can to help make the Bay healthy and safe again.

Source: Chesapeake Bay Foundation, Geography and facts: https://www.cbf.org/about-the-bay/chesapeake-bay-watershed-geography-and-facts.html

Activity 3 (Explore/Explain): Algae in a Bottle

ACTIVITY DETAILS

Time: 2 class periods + intermittent time to collect visual and dissolved oxygen data

Objectives

- ✓ Students will perform an experiment to determine the effects of excess nitrogen in natural bodies of water
- ✓ Students will understand that eutrophication, nutrient pollution (specifically nitrogen), and dead zones are all connected

Materials

- ✓ Materials for Algae in a Jar experiment (see below)
- ✓ Dissolved oxygen test kit
- ✓ Additional glassware (ex test tubes) so multiple students can test at the same time
- ✓ For clues wall: "Lots of algae in the Bay before fish died"
- ✓ Algae in a Bottle Teacher Guide

Handouts

- ✓ Algae in a Bottle experiment procedure
- ✓ Data collection sheet
- ✓ Analysis & summary sheet

Activity summary: In this extended experiment, students explore the effects of algal blooms on dissolved oxygen levels of water in a system by growing their own algae blooms in water bottles. They also connect excess nutrients to excess algae growth. This will prepare them for understanding how nutrient pollution affects the Chesapeake Bay.

<u>Standards Connection</u>

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
SEP: Planning & Carrying Out Investigations, Constructing Explanations & Designing Solutions
CCC: Cause & Effect

Experiment Guide

There are a lot of options for this experiment regarding materials and timing. At the start of the module, be sure to check out the Algae in a Bottle Teacher Guide below to help prepare.

Warmup: What kinds of living things do you find in the Chesapeake Bay? Don't forget living things that are not animals!

- The purpose of this warmup is to connect with the previous day's activity, and to determine whether students remember that algae live in the Bay.

1. **Frame the activity:** Tell students that you have another clue about the dead fish in the Bay. Before the dead fish appeared, scientists noticed that there was something strange about the water. It looked like this (show picture below). They thought there might be a connection between the color and the dead fish, but they had to find out for sure. We are going to start an experiment today to see what might cause this color in the Bay, and whether that might have caused the fish to die.

2. **Introduction to algae:** Ask students what they notice about the color in the picture. Key things for them to see are: it is a green color, it is closer to the shore than the center of the Bay, it seems almost like it is in waves. Ask students if they have any ideas what this color might be. Use questioning to help them realize that what they are looking at is a large quantity of algae. Lead a short discussion to see if/what students already know about algae. Then show them these pictures:

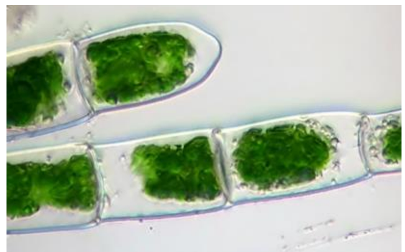


Photo by Felix Andrews (Floybix) - Own work, CC BY-SA 3.0,

Ask if any students have seen anything like the first picture. Tell them that the first picture shows algae growing in a pond. When this happens, it is called an algae bloom. The second picture shows what some algae look like under a microscope. Ask if students know why they have a green color. Use questioning to help students recognized that they can make their own food like plants (you don't need to discuss photosynthesis and chloroplasts). Students will learn more in depth about algae in Activity 4. Add the clue "Lots of algae appeared in the Bay before the fish died" to your clues board.

3. **Algae experiment setup:** Tell students that they are going to be performing an experiment to see if the algae are causing the fish to die. To do that, they are going to grow their own algae to observe what happens. Collaborate with students to develop a research question such as "How do algae affect the water they are growing in?" Hand out the "Algae in a Bottle Experiment Procedure" to students, and have them write the research question in the space at the top.

   Have students read through the materials first. When they get to the fertilizers, tell them that the different fertilizers will help the algae to grow. You don't need to go into detail at this point about why you are adding these particular fertilizers, but students will begin to understand in later activities in the module.

TEACHER NOTES

Source

- ✓ This experiment is based on "Bloomin' Algae!" https://www.education.com/science-fair/article/eutrophication/ which is itself based on "Eutrophication Lab" by D. Gioffre.

Modification

- ✓ If you are very pressed for time, another option for this experiment is to have students set up the containers, and then show them pictures of what it would look like along the way and give them sample dissolved oxygen data. This is not recommended, but it is a possibility.
- ✓ Phosphate is not a focus of this unit, so if you want to use just two bottles (control and nitrogen) or split up the experiments so that different students have different bottles (nitrogen, phosphate, nitrogen + phosphate) you can limit the amount of materials needed.

TEACHER NOTES

Differentiation

- ✓ Adjust the level of data analysis for the experiment based upon students' grade level and what they are studying in math. By 8th grade, they should be able to calculate the rate of change of dissolved oxygen for each graph. At lower grades, you may want to stop at having them compare the difference between the starting and ending DO amounts in each bottle.

Read through the procedure with students and check to make sure they understand what each of the bottles is for. When students are ready to begin, divide them into groups and have them complete the Setup Day portion of the procedure. Make sure that students make observations of their bottles on Day 1. Since all their data will be the same, you can test the dissolved oxygen on the first day together to teach students how to use the kits. Use a mix of pond water and bottled water like in their experiments. Before testing, briefly explain to students what "dissolved oxygen" means (they will learn more about this in Activity 4).

4. **Observations and D.O. testing:** At regular intervals (ex. every two days), have students make observations of their bottles. Halfway through the experiment, have students test for dissolved oxygen in each of the bottles and record the data on their data sheets. On the last day of the experiment, have them test the dissolved oxygen one more time.

By the end of 14 days, the bottles will look something like this:

5. **Results:** Have students graph their data for dissolved oxygen (you may choose to have them pool their data first). Discuss with students what kind of graph would be most appropriate. In this case, a line graph works best to show the change over time. Students should graph all their data on one set of axes to make comparison easier. They can use different colors or symbols for the different bottles. If technology is available, students can use Excel or Google Sheets to make their graphs.

6. **Analysis:** Have students analyze the change in dissolved oxygen (see note re: differentiation for different math levels), and describe the changes in the appearance of the bottles.

7. **Discussion:** Lead a class discussion with students about what their data means in the context of the experiment. Use the CER below as a guide to drive the discussion.

8. **Conclusion (formative assessment):** Make sure students have already completed Activity 4 before they do this section of this activity so they can make logical deductions about what happened in each of the bottles. Have students write a claim-evidence reasoning statement explaining their results. Because of the complexity of this CER, students will likely need some scaffolding and support. A sample explanation might be:
   - Claim: Algae grow fastest when there are extra nutrients in the water. The more algae there are, the more decomposers there will be to decompose them, causing the dissolved oxygen in the water to go down.
   - Evidence: In the bottles with the most fertilizer, we could see the most algae growing. In the bottle with no fertilizer (control) there was only a little algae growing. The bottles with the most algae and fertilizer had the least dissolved oxygen at the end, and the bottle with the least algae (control) had the most dissolved oxygen at the end.
   - Reasoning: Algae need nitrogen and phosphorus to grow. When they have extra nitrogen and phosphorus, more algae will grow. Eventually the algae die and decompose. Decomposers use oxygen to break down the algae. In the bottles with the most algae, there were more decomposers, so they used more oxygen, causing it to go down the most.

TEACHER NOTES

Differentiation

✓ If this is the first time students have written a claim-evidence-reasoning statement, be sure to scaffold appropriately (ex. give them sentence starters, write a simple example with them about a different topic, etc.). The discussion should also prepare them for writing the CER.

Modification

✓ Depending on where students are in the module, you can also connect the low D.O. levels back to the original phenomenon.

Name ____

STUDENT HANDOUT

Algae in a Bottle: Experiment Procedure

Research Question: ____

____

Materials

- ❒ 4 plastic ½ liter (500 ml) bottles or jars. The bottles should be the same or similar.
- ❒ Cheesecloth cut into small squares
- ❒ Rubber bands
- ❒ Masking tape
- ❒ Pond water
- ❒ High nitrogen fertilizer
- ❒ High phosphate fertilizer
- ❒ Bottled water
- ❒ Measuring cups and spoons
- ❒ Dissolved oxygen kit (from aquarium shop)
- ❒ Camera (optional)

Procedure for Setup Day (Day 1)

1. Label the bottles or jars with masking tape and a magic marker. The four labels should be: Control, Nitrate, Phosphate, Nitrate + Phosphate. Put your group initials on the labels so you know which bottles are yours.

2. Fill each bottle with 250 ml of pond water and 250 ml of bottled water. Use the measuring cups to be sure you put the same amount of water in each jar.

3. Add ½ teaspoon fertilizer to the jar that says Nitrate, and ½ teaspoon fertilizer to the bottle that says Nitrate + Phosphate.

4. Add ½ teaspoon detergent to the bottle that says Phosphate and ½ teaspoon detergent to the bottle that says Nitrate + Phosphate.

5. Cover the top of each bottle with a piece of cheesecloth and hold it tight with a rubber band.

6. Record observations of each bottle in the space on your data sheet that says Day 1. Make sure to observe the color of the water, if it is cloudy or clear, and if there is anything floating or growing in it.

7. Put the bottles in a sunny location.

8. As a class, mix 250 ml of pond water and 250 ml of bottled water. Then test the dissolved oxygen level of the mix using the procedure on your test kit. Write the dissolved oxygen level on your data sheet for Day 1.

Name ________________________________

STUDENT HANDOUT

Algae in a Bottle: Results & Conclusions

Results

Create a graph showing how the dissolved oxygen level has changed for each of your bottles. Use one set of axes for all of your data. Make sure to include a key to show what bottle each set of data represents.

Analysis

- How much did the dissolved oxygen amount change for each of the bottles?
  - Control: ________________________________
  - Nitrogen: ________________________________
  - Phosphate: ________________________________
  - Nitrogen + Phosphate: ________________________________

- How did the appearance of each bottle change from the start to the end of the experiment?
  - Control: ________________________________
  - Nitrogen: ________________________________
  - Phosphate: ________________________________
  - Nitrogen + Phosphate: ________________________________

Conclusions

Write a claim-evidence-reasoning statement to explain the change in dissolved oxygen levels and appearances for the bottles. In your statement, be sure to:

- Write a claim that answers your research questions
- Include your dissolved oxygen data and your observations in your evidence
- Use what you know about fertilizer (nutrients), algae, and decomposers to explain your evidence and prove your claim.

STUDENT DATA SHEET

Name ____________________________

Algae in a Bottle Data Sheet

Procedure for Days 2-14

1. Record your observations of the bottles using the data sheet. If you have a camera, take photographs of the bottles to show the changes.

2. On Day 7 and Day 14, take water samples from your bottles and test them for dissolved oxygen using the directions on your test kit. Record the dissolved oxygen level on your data sheet.

Day #	Observations	Dissolved oxygen (ppm)
1 Setup Day	**Control:** **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**	**Starting dissolved oxygen level:**
	Control: **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**	**Control:** **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**
	Control: **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**	**Control:** **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**

	Control: **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**	**Control:** **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**
	Control: **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**	**Control:** **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**
	Control: **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**	**Control:** **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**
	Control: **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**	**Control:** **Nitrogen:** **Phosphate:** **Nitrogen + Phosphate:**

TEACHER GUIDE

Algae in A Bottle Teacher's Guide

Timing Considerations

This activity takes one day to set up, plus intermittent time for students to collect data, then time at the end to analyze the data and draw conclusions. Overall, the experiment takes about 2 weeks, but only one whole class period at the beginning, and one at the end.

There are few recommended options for timing:

- **Option 1:** Start the experiment right after Activity 1, and then check in with the results as time goes on. This has the benefit of helping students understand what they are setting up. However, students won't get results until later in the module.
- **Option 2:** Start the experiment in advance of the module so they will be able to draw conclusions by the time you get to this Activity. This has the advantage of providing results earlier, but students won't really understand why they are setting up the experiment.
- **Option 3:** Start one set of algae bottles in advance so that students can see the results earlier, then have them start their own experiments during the module. This way students can see results earlier, and also know why they are setting up the experiment. The downside to this is that students will know what happens in the experiment before their own bottles are done.

All three options have benefits and drawbacks. Choose the option that works best for you and your students.

Materials

Bottles: The experiment calls for 4 bottles or jars per group of students. The bottles should ideally be the same within a group, but they can be different for different groups. Consider having students bring in bottles or jars from home to use. If absolutely necessary, you can buy packs of water and use the bottles. The amounts for this experiment are based on 500ml bottles.

Fertilizers: The experiment calls for high nitrate and high phosphate fertilizers. You can find a variety of different fertilizers at local garden stores and online. For example, Amazon sells the two fertilizers below. You may be able to get a local garden store to donate them. Look for fertilizers that only have one of the two ingredients (nitrate or phosphate) to make the results more clear.

- Nitrogen fertilizer: Easy Peasy Plants Urea Nitrogen Fertilizer
- Phosphorus fertilizer: Easy Peasy Plants Triple Super Phosphate

Water: If you have nearby access to a pond or slow-moving stream that likely has algae in it, this is the easiest source. If you don't have access to either of these, you can likely get aquarium water from a local pet store that sells fish. You can also order blue-green algae from science suppliers such as Carolina. Make sure to get enough water for all your student groups.

Dissolved oxygen test kit: There are a variety of commercially available dissolved oxygen test kits that vary by price, accuracy, and ease of use. Generally speaking, the more accurate kits are more expensive, though not necessarily more difficult to use. Below are two suggested kits:

- Salifert Dissolved Oxygen Test Kit (less accurate, relatively easy, inexpensive)
- CHEMets Dissolved Oxygen Visual Kit (accurate, very easy, more expensive) – refill kits are less expensive

Activity 4 (Explain): Algae: The Silent Killer

ACTIVITY DETAILS

Time: 60 minutes

Objectives

- ✓ Students will interpret a graph and read a text to learn how algal blooms result in dead zones.

Materials

- ✓ Computer & projector
- ✓ Word wall words: dissolved oxygen, algae, algae bloom, decomposer

Handouts

- ✓ Reading: Algae & Dissolved Oxygen (double-entry journal)

Teacher Tip

- ✓ The "algae" in these graphs is actually a bacterium (cyanobacterium) which is called blue-green algae because it shares a lot like of characteristics with algae. You can bring this up with students, but don't let it distract from the overall purpose of the activity.

Activity summary: In this activity, students analyze graphs of data from Sykes Creek, a stream in Florida that was the site of a fish kill in 2016 (the fish kill isn't revealed to students until the end). After looking at the graphs of algae and dissolved oxygen, they read about the connection between algae, dissolved oxygen, and decomposers. Finally, they use what they have learned from the graphs and the reading to explain what caused the fish kill.

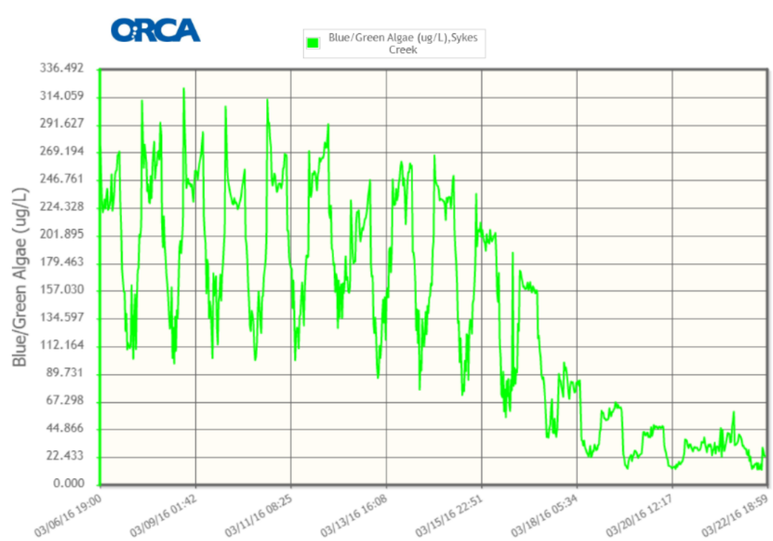
<u>Standards Connection</u>
DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
SEP: Constructing Explanations & Designing Solutions
CCC: Cause & Effect

Warmup: What happens to the bodies of animals and plants when they die? What other living things help out with this process?

- Answer: they decompose, break down, etc.; this is done mainly by bacteria and fungi, but also detritivores like worms and insects
- The purpose of this warmup is to gauge students' background knowledge on decomposition to prepare for the activity

1. **Frame the activity:** Tell students that as a class they need to do some research about algae to see how they could be connected to the dead fish in the Bay. To do this, they're going to analyze some graphs for algae growth from a place called Sykes Creek, and read a text about algae.

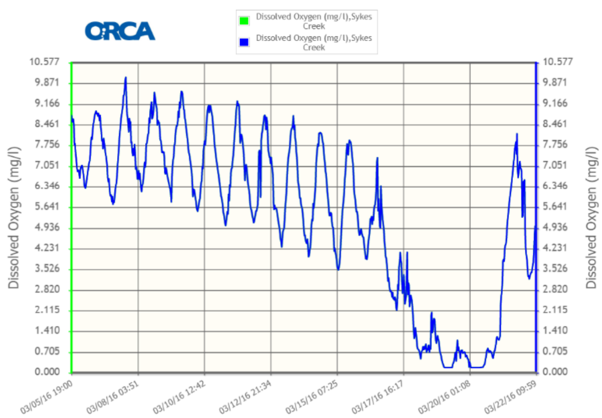
2. **Graph 1: Algae:** Hand out the Algae at Sykes Creek sheet to students and show it on a projector so students can see the color.



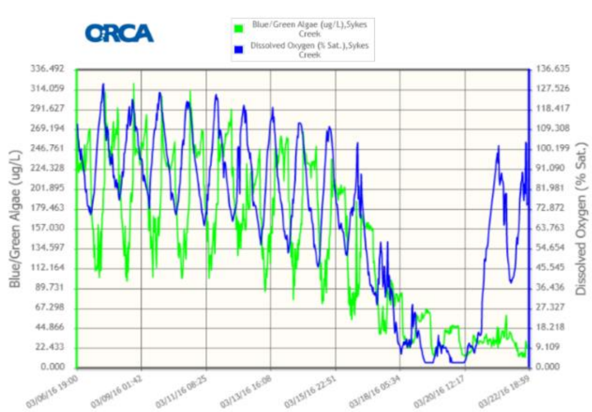
Make sure students understand that this is a graph of the amount of blue-green algae in a creek. Ask students what they notice about the graph.

Students should notice that the graph goes up and down a lot, and that it eventually goes down to a very low amount starting on March 15. Use questioning to help them realize that it goes up and down on a day/night cycle (up during the day, then back down at night). They will come back to this graph to think about why it went down so much at the end.

3. **Graph 2: Dissolved oxygen:** Display Graph 2 (Dissolved oxygen). Remind students that dissolved oxygen is just like oxygen in the air that is mixed into the water. Fish and other animals need dissolved oxygen to breathe underwater (they will learn more about it later in the activity). Have students share what they notice. They should see that it also goes up and down a lot, and then goes down to a very low level starting on March 15.



4. **Graphs 1 & 2 combined:** Show students Graph 3, which is Graphs 1 and 2 combined. Ask students what they notice. They should recognize that the two graphs fit together (the amount of blue-green algae and the amount of dissolved oxygen seem to be related up until the end). Ask students why they might be related.



TEACHER NOTES

Source Data

✓ The data source for these graphs is ORCA (Ocean Research & Conservation Association) based in Florida. The data comes from their public monitoring website: http://api.kilroydata.org/public/. More information about the March 2016 fish kills can be found here: http://blogs.ifas.ufl.edu/brevardco/2018/03/06/fish-kills-floridas-coastal-waters/

Discussion techniques

✓ For each of the graph discussions, consider using a turn-and-talk to have students share ideas with a partner before sharing with the whole class

TEACHER NOTES

Students may remember that algae make oxygen, so that could be one reason they are related. However, that doesn't explain why they both went down starting on March 15th. Depending on where students are with their Algae in a Bottle experiment, they may also be seeing similar results in their own data. Use discussion to help students reach the question: "Why do the algae and dissolved oxygen both go down at the same time?"

5. **Building background knowledge reading:** Hand out the double-entry journal reading "Algae & Dissolved Oxygen." Have students read and answer the questions.

6. **Discussion:** Have students share out key information they learned from the reading. Put up the word wall words dissolved oxygen, algae, algae bloom, and decomposers. Key ideas that students should share from the reading:
   - Algae are unicellular or multicellular living things
   - Algae can produce their own food and oxygen using sunlight
   - Algae can increase the amount of dissolved oxygen in the water
   - When there are too many algae, they die out and get broken down by decomposers
   - Decomposers use up the dissolved oxygen

7. **Return to Sykes Creek:** Have students go back to their graphs of Sykes Creek. Remind them of the drop on March 15th. Have them turn to a partner and talk about what they think happened starting on that day. Students should be able to connect their reading to the data to recognize that there were too many blue-green algae, and so they died. When they decomposed, the decomposers used up the dissolved oxygen, causing it to drop. After their turn and talk, have groups share out their conclusions.

8. **March 20, 2016:** Remind students of their original mystery (the dead fish in the Chesapeake Bay). Point out key clues that they've learned:
   - Dead fish in the Chesapeake Bay
   - Lots of algae appeared in the Bay before the fish died

   Have students add any more clues from today's activity such as:
   - When there is too much algae, they die, and the amount of dissolved oxygen goes down

TEACHER NOTES

Tell students that the reason they've been studying Sykes Creek in March 2016 is that it was the site of another mystery. Ask students if they can predict what happened at Sykes Creek on March 20th 2016 (point out the data on the graph). They may or may not be able to guess what happened. In either case, show them this photo:

Photo taken Mar 20

Use questions and discussion to help students realize that when the dissolved oxygen level gets too low, it will kill the fish. Have them add a clue to their clues board such as:

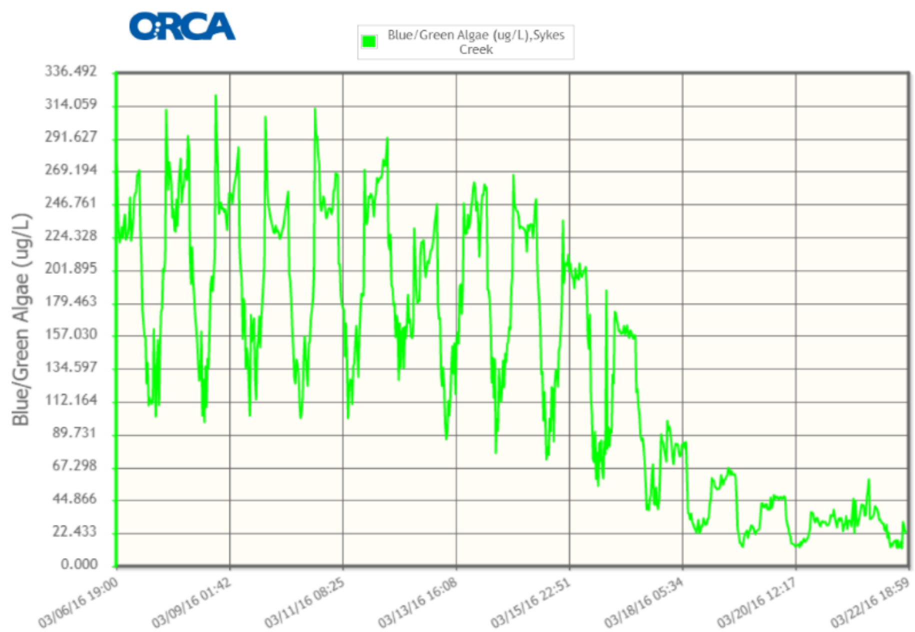
- Low dissolved oxygen can kill fish

9. **Formative assessment:** Have students answer the prompt on their graphs sheet as a narrative (or Claim-Evidence-Reasoning argument) explaining what caused the fish to die in Sykes Creek based on what they learned today. For example:
    - Claim: The fish died because there was not enough oxygen due to too many blue-green algae.
    - Evidence: On March 15, the amount of blue-green algae went down a lot. The amount of dissolved oxygen also went down a lot.
    - Reasoning: The amount of blue-green algae went down because there were too many and they blocked out the sunlight so they could not make enough food. When they decomposed, the decomposers used up the oxygen in the water. Because there was not enough oxygen, the fish couldn't breathe and they died.

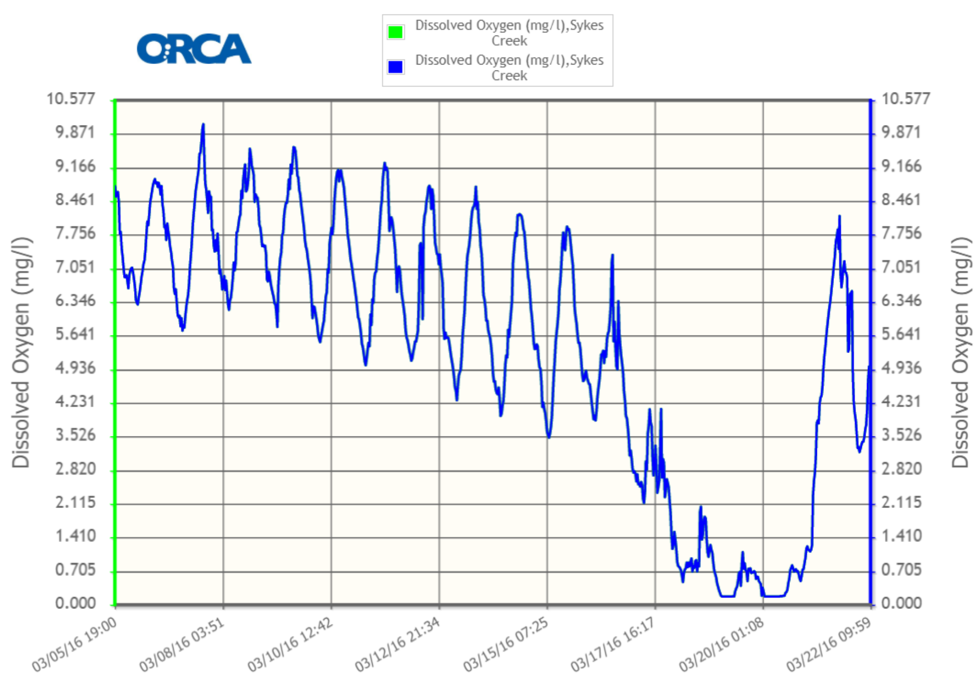
Name____

STUDENT HANDOUT

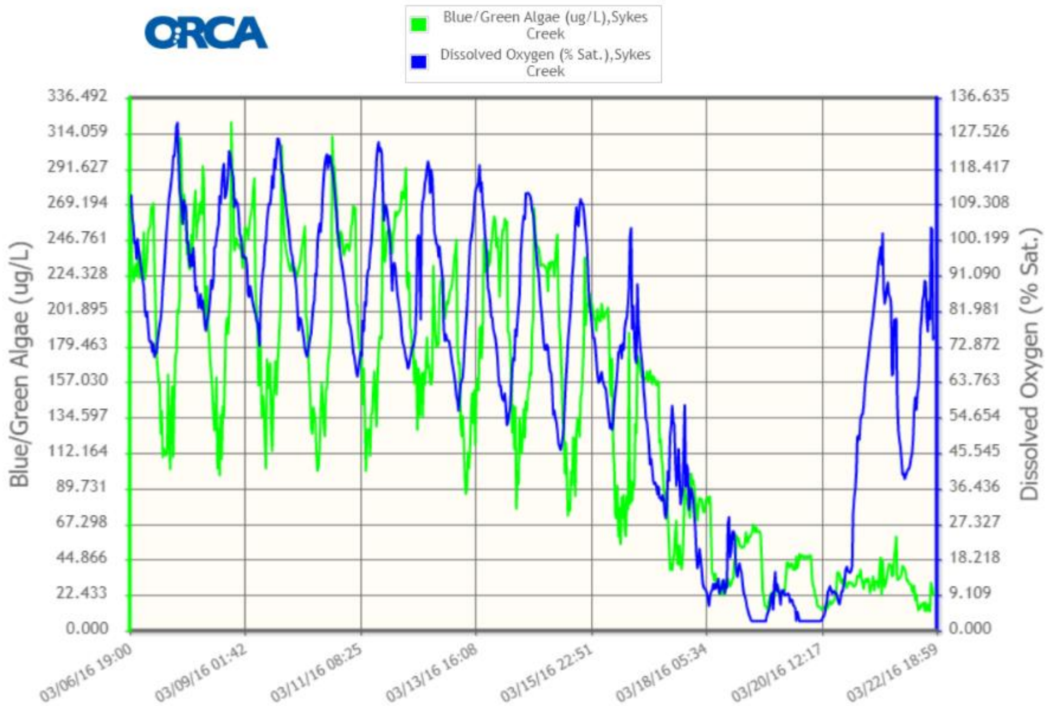
Blue-green Algae at Sykes Creek



Graph 1: Blue-Green Algae at Sykes Creek



Graph 2: Dissolved Oxygen at Sykes Creek



Graph 3: Blue-green Algae and Dissolved Oxygen at Sykes Creek

<u>Conclusion</u>

Explain what happened on March 20th in Sykes Creek using what you learned today from the graphs and the reading about algae and dissolved oxygen.

Name ______________________________

STUDENT READING

Algae & Dissolved Oxygen

Algae are living things that grow in all different kinds of water around the world. If you have ever looked at a pond and seen green scum on top, you're looking at algae! Algae can be very small, single-celled organisms, or they can be large multicellular organisms. Algae can also clump together to form thick mats which can completely cover the surface of a lake or pond. They can also grow into big "forests" in the ocean.	**Have you ever seen algae before? Where?**
There are many different kinds of algae. There is also a bacteria, called blue-green algae, which is not algae at all! It just gets its name because it has many similar characteristics as algae. The most common characteristics of algae are: they live in all types of water (freshwater and saltwater) and they conduct photosynthesis. This means that they can use sunlight to make their own food, just like plants. However, unlike plants, algae do not have roots stems, or leaves.	**What are common characteristics of algae?**
Photosynthesis makes food, and it also produces oxygen. When algae make oxygen, it is often dissolved in the water. When something is dissolved in water, it means it is mixed in with the water molecules. For example, if you stir sugar into a glass of iced tea, the sugar will dissolve into the tea. Dissolved oxygen is oxygen that is mixed into the water. Fish, crabs, shrimp, and other animals that live in water need the dissolved oxygen to breathe, just like we need oxygen in the air to breathe.	**Where does the oxygen go that algae make?**
Algae can help add oxygen to the water, but sometimes there can be too much algae. This is called an algae bloom. During an algae bloom, the algae blocks the sunlight from getting into the water. This causes the algae and underwater plants to die. When the algae die, decomposers like bacteria and fungi break down the algae. This uses oxygen. When there is a lot of dead algae, the decomposers use a lot of dissolved oxygen up from the water.	**What do you think happens to the amount of dissolved oxygen in the water if there is too much algae?**

Activity 5 (Explain): Where is the Pollution Coming From?

Activity summary: In this short activity, students study an infographic to learn that the main source of nitrogen pollution to the Bay is from agriculture and air pollution. They use this new information to help understand where the algae bloom came from.

Standards Connection
DCI: ESS3.C: Human Impacts on Earth Systems
CCC: Cause & Effect

Warmup: What do plants need to grow?

- The purpose of this warmup is to start laying the groundwork for students to make the connection between nutrient pollution and algae blooms. They will likely say things like water, air, sunlight, and soil. During the warmup discussion, ask students what plants need from the soil. If they don't know ask them if they've ever grown a plant or know someone who grows vegetables or flowers. Ask what they put on the soil to help their plants grow? (fertilizer). Students will discover some additional information about this later in the activity, so don't give away too much at this point. The goal is just to help students start making this connection.

1. **Frame the Activity.** Return to the clues board that you've been developing about the what killed the fish in the Bay. So far you should have at least these three clues (or something similar to them):
   - Dead fish in the Chesapeake Bay
   - Lots of algae appeared in the Bay before the fish died
   - When there is too much algae, they die, and the amount of dissolved oxygen goes down

   Ask students if they think they can solve the mystery of what caused the fish to die. Have them turn to a partner to share what they think happened. At this point, students should be able to explain:
   - The fish died because they didn't have enough oxygen to breathe (they suffocated). There was too much algae from the algae bloom so when the algae died and decomposed, the decomposers used up all the oxygen, so there wasn't enough for the fish.

ACTIVITY DETAILS

Time: 30 minutes

Objectives

✓ Students will be able to name the primary sources of nitrogen pollution to the Chesapeake Bay

Materials

✓ Computer & projector

Handouts

✓ Where is the Pollution Coming From?

Timing Tip

✓ Because this activity is on the shorter side, it works well on a day when students are also making observations of their Algae in a Bottle experiments.

ACTIVITY DETAILS

Timing note

- ✓ If students are already into Week 2 of their Algae in a Bottle experiments, they may have an idea of where the algae came from. Tie this in as much as possible to help students make the connection between the algae bloom and nutrient pollution.

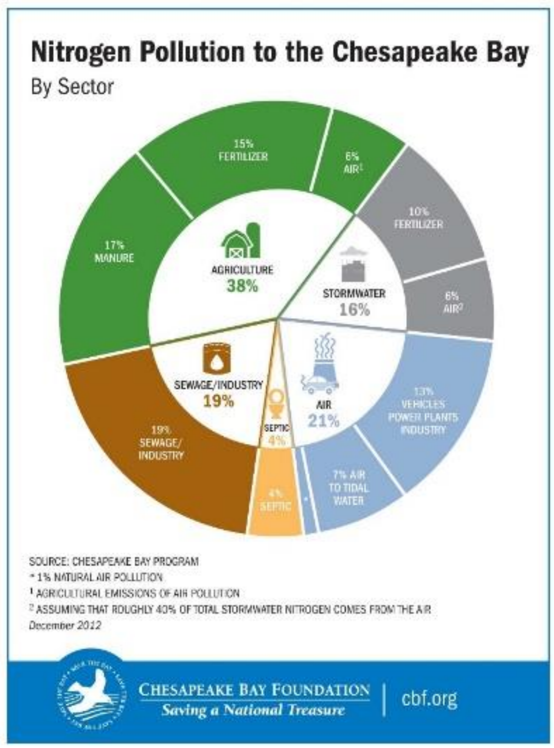
Note on Source Data

- ✓ The information in this infographic is constantly changing due to changing human behaviors and land use. Scientists like Lewis Linker (our Air Quality Champion for this module) create models to better understand all the nutrient inputs into the Bay to better understand the source of the problem. While more updated percentages may be available, the general sources of the pollution have not changed significantly.

If all students haven't quite reached this stage of articulating an answer, it is okay, because they will have additional time in the future. As long as some students can reach this point, tell them that they're close to solving the mystery, but there's still at least one more question they need to answer: **Where did all the algae come from?** Tell them that during class today they're going to begin investigating that question.

2. **Fiendish fertilizer:** Remind students that one of their "I wonder" questions from the Chesapeake Bay video was about pollution in the Bay. Tell students that there are four main kinds of pollution that enter the Chesapeake Bay: toxic chemicals, nitrogen, phosphorus, and sediment (ex. sand). Go through each one, and ask students whether they think it could have caused the algae to grow into a bloom. Use questions to help them remember that nitrogen and phosphorus are in fertilizer (they should be able to remember this from their algae experiments). Help them reach the conclusion that nitrogen and phosphorus are likely what is causing the algae to grow.

3. **Where is the pollution coming from?** Ask students where they think the majority of this pollution is coming from? Acknowledge students' responses, but don't give away whether they are right or not. Next, hand out the "Where is the Pollution Coming From?" sheet for students and have them use the infographic to answer the questions.



Afterwards, lead a short discussion to ensure students understand the key takeaways:

- The majority of nitrogen pollution to the Bay comes from agriculture.
- 25% of the nitrogen pollution comes from fertilizer
- 33% of the nitrogen pollution comes from air pollution
- Nitrogen pollution from manure and fertilizer is washed into the Bay (more on this in the next activity)
- Nitrogen pollution from sewage and industry comes from sewage that is dumped into tributaries or into the Bay directly. It also comes partly from people dumping into the Bay.

Ask students if they were right in their guess about where the nitrogen pollution is coming from. Then ask them how they think pollution in the air gets into the Bay. Again, don't tell them if they are right or wrong, just acknowledge their guesses. The point of this question is to get their minds thinking about how air pollution could possibly get into the water.

4. **Return to the clue board:** Go back to the clue board and see if there are any more clues to add. For example, you might add:
    - Nitrogen and phosphorus pollution are causing the algae bloom
    - Most nitrogen pollution comes from agriculture

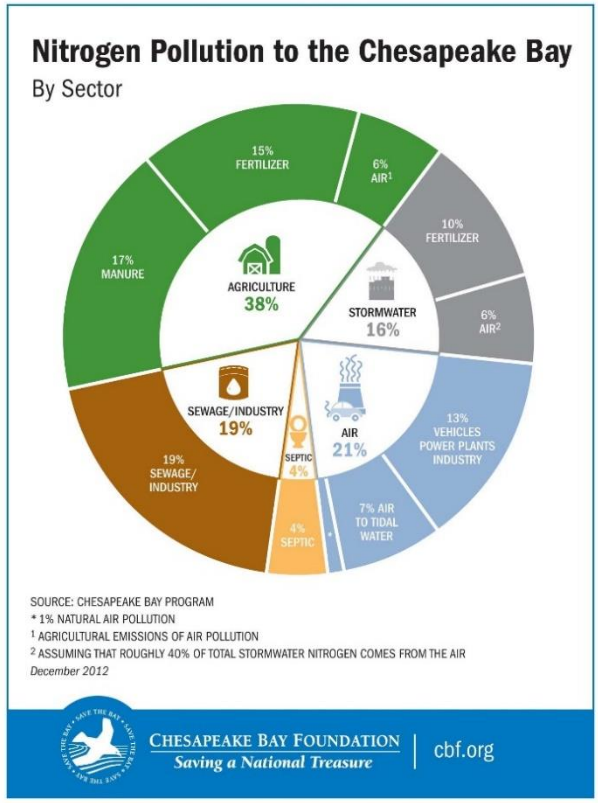
    Tell students that they now have a good idea what is causing the fish to die, but if they want to stop the problem, they need to go to the source of it.

5. **Formative assessment:** Have students complete the "Conclusion" prompt on the back of their sheet: Do you think most of the pollution in the Bay comes from people dumping it into the water on purpose? Use information from the infographic to support your answer.
    - Answer: No, most of the nitrogen pollution to the Bay is unintentional. It is from pollution from the land and the air that ends up in the Bay accidentally. Only a small portion of the pollution in the Bay is dumped there intentionally.

STUDENT HANDOUT

Name ______________________________

Where is the Pollution Coming From?



1. What sector (ex. sewage/industry, air, etc.) does the largest portion of nitrogen pollution to the Bay come from?

   ____

2. What percentage of the nitrogen pollution to the Bay comes from fertilizer? (make sure to look in all sectors):

   ____

3. What percentage of nitrogen pollution to the Bay is air pollution? (make sure to look in all sectors):

   ____

4. How do you think nitrogen pollution from things like fertilizer and manure gets into the Bay?

   ____

   ____

5. How do you think nitrogen pollution from things like sewage and industry gets into the Bay?

   ____

   ____

Conclusion

Do you think most of the nitrogen pollution in the Bay is dumped there intentionally? Use information from the infographic to support your answer.

Activity 6 (Explore/Explain): Rain, Pollution, and Watersheds

ACTIVITY DETAILS

Time: 45 minutes

Objectives

- ✓ Students will be able to define watershed, geosphere, and hydrosphere, and explain how they connect
- ✓ Students will be able to describe how land-based nutrient pollution gets into the Chesapeake Bay
- ✓ Students will know that some pollution gets into the Bay when it washes off the land

Materials

- ✓ Plain paper (enough for all students.
- ✓ Spray bottle(s) with water (one or more)
- ✓ Water-soluble markers (see below for more details) – enough for all students
- ✓ Paper towels for cleanup
- ✓ Crumpled Paper Watershed teacher guide
- ✓ Word wall words: watershed, geosphere, hydrosphere
- ✓ Computer & projector

Handouts

- ✓ Watershed Notes sheet

Activity summary: In this activity, students learn about watersheds, and how pollution that is initially on the land gets into the water. They do this by making a simulated watershed from a crumpled piece of paper, and then "raining" on the watershed to wash pollution into waterways. Using their paper watersheds, students create definitions and apply their definitions to understanding the Chesapeake Bay watershed.

<u>Standards Connection</u>

DCI: ESS3.C: Human Impacts on Earth Systems

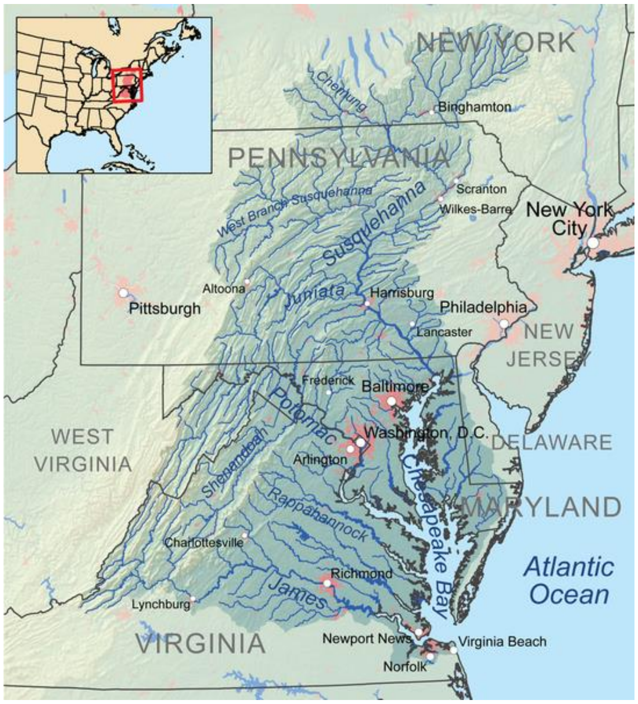
Warmup: Where would you find things like manure and fertilizer? What about other kinds of animal feces?

- Use this warmup to help kids make the connection that these things are often found on farms, but they also are commonly found in other places too. Pet feces are a major contributor to pollution in Rock Creek Park (DC) and fertilizer from lawns is a problem in both urban and suburban communities. You can use the graphic from the previous activity to point out that "fertilizer" appears in both the agriculture sector and the stormwater sector.

1. **Frame the Activity:** Remind students that during the last activity, they shared some ideas about how pollution on the land gets into the water. For example, how manure from a farm or fertilizer from a lawn might get into the water. Today they're going to figure out how that happens. Since a lot of the nitrogen pollution that is making the algae grow is coming from the land, figuring out how it gets into the water will provide some clues as to how to stop it.

2. **Crumpled paper watershed.** Follow the teacher guide below to lead this activity with students. Make sure to clean up before moving to the next part of the activity so the wet watersheds are not a distraction.

3. **Defining the Chesapeake Bay watershed**: Ask students to think about the Chesapeake Bay watershed. Where do they think the Chesapeake Bay watershed is? (It is the area of land around the Chesapeake Bay. Put up a map of the Chesapeake Bay watershed like the one below and point out the area of land that is the Bay's watershed.



ACTIVITY DETAILS

Have students turn to a partner and talk about what they notice about the Chesapeake Bay watershed. When they are ready, have students share with the class. Use questions to help make sure they identify key takeaways:

- The area of land around the Bay is much larger than the Bay itself.
- The map has lots of rivers marked on it (because these rivers all flow into the Bay)
- The watershed is in many states (6 + Washington, DC).
- They live in the Chesapeake Bay watershed.

Point at different parts of the map, and ask students "If it rains here, where will the water go?" Point to parts of the map that are in the watershed, and not in the watershed. You can be specific about where the water will go before it gets to the Bay (ex. it goes into the Susquehanna River and then into the Chesapeake Bay), but the key is that all the water in the Chesapeake Bay watershed goes to the Bay. Have students write the definition of the Chesapeake Bay watershed on their notes sheet: "All the land that drains its water into the Chesapeake Bay."

4. **Defining geosphere & hydrosphere**: Put the word "geosphere" on the word wall. Ask students if they know what the prefix "geo-" means as in "geography" or "geology". Use student responses to help them understand that geo- means Earth or land, and that the "geosphere" is

Teacher Tip

✓ Most of the land to the west of the Chesapeake Bay watershed is in the Mississippi River watershed. To the south is the North Carolina Sound watershed, to the east is the Delaware River and Atlantic Ocean watersheds, and to the north is mostly the Hudson River and Great Lakes watersheds.

TEACHER NOTES

NGSS-Connection

- ✓ The terms geosphere and hydrosphere (along with biosphere and atmosphere) are used extensively in NGSS, so brining these terms in here is designed to help students make the broader connection to Earth Science concepts. If you have already used these terms with students, this is a good time to make the connection to the atmosphere and the biosphere as well.

Phenomenon connection

- ✓ If it feels useful, take a moment to help students make a connection back to the original phenomenon. They're trying to figure out what made the algae grow so much. They know that it has something to do with nutrient pollution. The watershed helps them understand where the pollution is coming from.

the part of the Earth that is land. Ask students what part of the map represents the geosphere, and make sure that they understand it is the land.

Put up the word "hydrosphere" on the word wall. Ask students if they know what the prefix "hydro" means is in "hydrated" or "fire hydrant". Use student responses to help them understand that hydro-means water, and that the "hydrosphere" is the part of the Earth that is made of water including rivers, lakes, and streams. Ask students what part of the map represents the hydrosphere, and make sure that they understand that it is the water (rivers, the Bay, the ocean, etc.)

5. **Defining the watershed in terms of geosphere & hydrosphere.** Write or display the sentence: "A watershed map shows how the land connects to the water." Ask students what this sentence means. Use discussion to help students realize that a watershed map (like the Chesapeake Bay map they were just looking at) shows what land will drain into what water. In the sentence, replace the words "land" and "water" with "geosphere" and "hydrosphere" and ask students if the sentence still makes sense. Tell them that scientists use these words "geosphere" and "hydrosphere" to define the land and the water, just like they use the word "atmosphere" to talk about everything in the air.

6. **Formative assessment:** Have students explain in their own words how fertilizer from a lawn in Northwest Maryland could get all the way into the Chesapeake Bay.
    - Possible answer: When it rains, the fertilizer washes of the lawn and down into the storm drain. The storm drain connects to a local stream. That local stream connects to the Potomac River. The Potomac River connects to the Chesapeake Bay. So the fertilizer washes all the way from the lawn to the Bay.

TEACHER GUIDE

Crumpled Paper Watershed[1]

Materials
- ❒ Plain white paper (enough for every student to have a sheet)
- ❒ Water-soluble markers (enough for student groups to have a few different colors). These markers usually say water-washable. Markers that are not water-washable will not work!
- ❒ Spray bottle with water
- ❒ Paper towels for cleanup

Directions
1. Tell students that for this activity they are going to create a landform that they can use to learn about how pollution gets into the Bay.

2. Pass out a sheet of blank paper to every student and provide water-soluble markers to groups of students so they have a few different colors. Tell students that this piece of paper will represent the land around where they live like a map

3. Have students draw an overhead view on their paper of things like houses, the school, and other things in their community (don't include any water features (rivers, lakes, etc.). Give them enough time to draw a few different things, but not fill the whole paper

4. Go back to students' answers from their warmup, and remind them of different sources of pollution such as farms and animals. You can suggest one or two things from the previous activity's infographic such as a power plants and factories. Have students choose a different color marker and add these sources (as drawings) to their paper.

5. Remind students that the land is not completely flat. To add contour (high and lows) to their map, they should crumple the paper up into a ball, and then un-crumple it without flattening it. Their uncrumpled map should have a lot of high points and low points.

6. Tell students that it is about to rain. On their notes sheet, have them predict what will happen when it rains on their land. When they are ready, have students put their papers on paper towels or trays to help with clean-up. Take out a spray bottle (or pass spray bottles out to students), and gently spray down onto each students' map. You should spray enough that water flows down to the low points and forms tiny ponds, but not so much that the entire paper becomes soggy.

7. Have students make observations and answer the questions on their Watershed Notes Sheet. Some things they should notice:
    - Water flows down and forms small ponds in the lower places (and/or makes a pool off the side of the map)
    - The colors from the "pollution sources" flow with the water into the ponds, polluting them
    - The paper (ground) also gets wet as the water soaks into it

8. Lead a class discussion about the results of the demonstration:

[1] Based on Crumped Paper Watershed, Alice Ferguson Foundation: http://fergusonfoundation.org/teacher_resources/crumpled_paper.pdf

- **Based on this model, how do you think pollution that is sitting on the ground gets into waterways?** Pollution washes off the ground and goes downhill into the closest body of water like a river or a stream
- **How do you think pollution that is on the ground gets into the Chesapeake Bay?** (It may be useful to show the Chesapeake Bay map here to remind students of how the rivers flow into one another). When pollution goes into a river, that river connects to the Bay or to another river that connects to the Bay.

After the discussion, have students write the answers to these questions in the Analysis section on the back of their Watershed Notes sheet.

9. Ask students if all the water that they sprayed on their paper ended up in the same place. (The answer is likely no for most students). Have them pick one of the "bodies of water" where their water ended up and give it a name like "Lake Sarah" or "The Sparkling Ocean". Once they've done this, ask them what part of their paper sent or drained water into "Lake Sarah". Can they point to it? Could they draw a line around it? (Circulate and help students point out the areas where their water came from – it should only be parts of the paper that are close by and not separated by a high point)

10. Ask students where the pollution in Lake Sarah came from (it is the same area they just pointed out). Tell students that scientists give a special name to this area of land to help them study pollution for a body of water like their little lake. They call this area of land "the watershed" (put this term up on the wall) and have students write a definition of watershed on their notes sheet: "A watershed is an area of land that drains into a specific body of water."

11. Tell students that the watershed is named after the body of water it flows into like "The Potomac River watershed". Ask students what the watershed they pointed out would be called ("Lake Sarah watershed" or "The Sparkling Ocean watershed"). Tell students that they can remember what a watershed is because a watershed "sheds it water" into a river, lake, ocean, or other body of water.

12. Clean up students' papers before moving on to the next part of the activity. If students want to keep their papers, pour out the extra water and find a place in the classroom where they can dry and keep their shape.

STUDENT HANDOUT

Name ____

Paper Watershed Notes

Before the Rain

What do you think will happen when it rains on your land?

After the Rain

What do you see on your land after the rain?

Where does the water go?

What happened to the “pollution” from your different sources?

What happened to the “ground” (your paper)?

Analysis

How does pollution that is on the ground get into the water?   How does pollution from the ground get into the Chesapeake Bay?

Understanding Watersheds

What is a watershed?
What is the name of the watershed on your map?

The Chesapeake Bay Watershed

What is the Chesapeake Bay watershed?

Activity 7 (Explore): How Do Gases Get Into Liquids? (optional)

Activity summary: For this activity, students use a variety of phenomena including weathered and eroded tombstones, dissolving salt, and carbonated soda to explore the concept of dissolved substances. This is designed to lead them to an understanding of how gases can be dissolved in liquids, which will be important for understanding how air pollution can get into the Chesapeake Bay.

ACTIVITY DETAILS

Time: 30-45 minutes

Objectives

- ✓ Students will understand the concept of a gas dissolved in a liquid
- ✓ Students will understand that "polluted rain" can have a significant effect on objects

Materials

- ✓ Salt
- ✓ Cups of water
- ✓ Stirrer
- ✓ Bottle of carbonated beverage (ex. soda)
- ✓ Word wall words: dissolve

Handouts

- ✓ Disappearing Salt

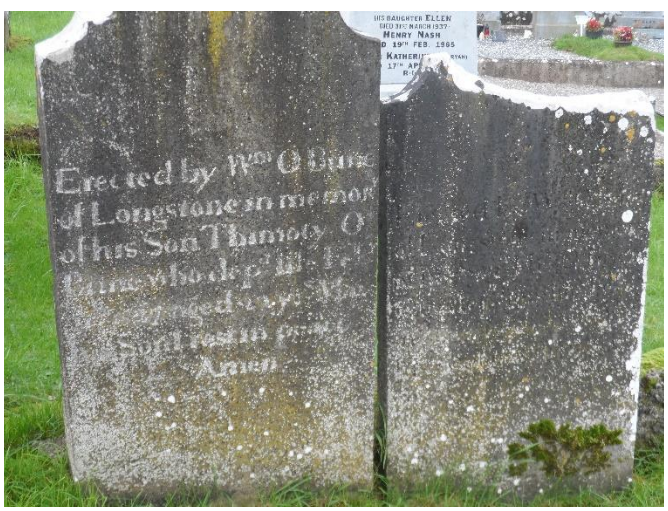
A Note about doing this activity

The activity after this one (Activity 8), as well as some of the activities before this one refer to gases dissolved in water, especially dissolved oxygen, dissolved nitrate, and dissolved ammonia. This activity is designed to help provide student background knowledge about how this is possible. It is not entirely necessary for students to understand gases dissolved in liquids to proceed through the module, so if you are pressed for time, it is okay to skip this activity. Nonetheless, it does provide valuable background knowledge for students, so if you have time, it is recommended.

Standards Connection

SEP: Constructing Explanations & Designing Solutions
CCC: Cause & Effect

Warmup: Show students a picture of monuments or tombstones affected by acid rain, such as the one below, and have them write what they think happened to the monument/tombstone:



TEACHER NOTES

Teacher Tip

- ✓ This definition of the word "dissolve" is somewhat basic, but it is enough to help students understand the concept of something dissolving in something else. If your students have already studied phases of matter, consider showing students a model of what a solid or gas dissolved in a liquid looks like at the particle level, such as this one: https://qph.fs.quoracdn.net/main-qimg-55842a14783b241e28e9fbf7f1b13033.webp

Depending upon what they have already learned, students may discuss weathering and erosion, or them may say things like a piece broke off or the letters wore off. Use their responses as a way to gauge student background knowledge on the concept of acid rain and weathering/erosion, but do not give them a definitive answer.

1. **Frame the Activity**: Remind students that during the last activity, they investigated how pollution from the ground gets into the Chesapeake Bay. Show them the infographic from Activity 5 and remind them that 1/3 of the nitrogen pollution in the Bay comes from air pollution. How is that possible? How does air pollution get into the Bay? Today they are going to start answering that question.

2. **Dissolving a solid in water**. Pass out the "Disappearing Salt" handout. Then give each pair of students a small cup of water, a tablespoon of salt on a paper towel, and something to stir with. Have students write observations about the salt and the water on their sheets. For example, the salt is a solid, it's white, it's hard, it's opaque; the water is a liquid, it's colorless, it's clear.

   Have students mix the salt into the water, and then make an observation of what they see. For example: the salt slowly disappears. The mixture is a clear, colorless liquid.

   Ask students if they think the salt is still in the water. How can they tell? (If permitted, and students are interested, you can have one student from each group taste the water to verify that the salt is still in it).

   Ask students if they know what happened to the salt – some may know that the salt "dissolved" in the water. Put the word "dissolve" up on the word wall, and ask students what this means. Help them to develop the definition that when something dissolves in water it mixes with the water and changes form but it is still there. Have students write an explanation of what happened to the salt using the word dissolve in the space on their handout.

3. **Dissolving a gas in water:** Make sure students understand that the first example was a solid dissolved in a liquid. Ask them if they think gases can be dissolved in water. They should remember talking about dissolved oxygen earlier in the module, or they may have other examples.

   Take out a bottle of soda or another carbonated beverage. Have students write down observations of the liquid in the bottle in the "before" section of their paper. For example: it is brown, it is a liquid, it is opaque.

Ask students if they think anything is dissolved in the soda. They may say things like sugar or flavorings (which are correct). Ask students if they think there is a gas dissolved in the soda. They will likely know that there is.

Ask students how they could show that there is a gas dissolved in the liquid. There are many possible responses: when you open it, you can hear a sound, when you shake it or pour it, the gas will fizz, if you drink it you might have to burp, etc. After hearing student responses, have students prepare to make observations in the "after" section of their handout. Then shake the bottle and then open it so that the carbon dioxide is released quickly and becomes very visible (preferably over a sink or in a plastic bag). Have students write down their observations (ex. there are lots of bubbles coming out of the liquid, it changes shape, it changes color, etc.)

Ask students if they know what the gas is that was dissolved in the soda. Use questions to help them connect the idea of "carbonated" drinks with "carbon dioxide".

Have students answer the question at the bottom of their handouts: "What does it mean for something to be dissolved in something else" Student explanations should include the idea that the first thing changes form and mixes in with the other thing. Often the thing that is dissolved can no longer be seen.

Make sure students agree that solids and gases can both be dissolved in water. Have students think back to Activity 2 when they measured dissolved oxygen in water in order to help them make the connection that oxygen can dissolve in water, and that living things like fish need the dissolved oxygen to survive.

4. **Return to the tombstones:** Show students the picture of the tombstones again. Ask them again what they think may have happened to them. Use questions to focus their thinking around key ideas:
    - The tombstones are solid, but they partially washed away. Part of the tombstones must have dissolved in rainwater and washed away
    - Rainwater on its own is not strong enough to dissolve a tombstone
    - Something must be in the rainwater that allows it to dissolve the stone

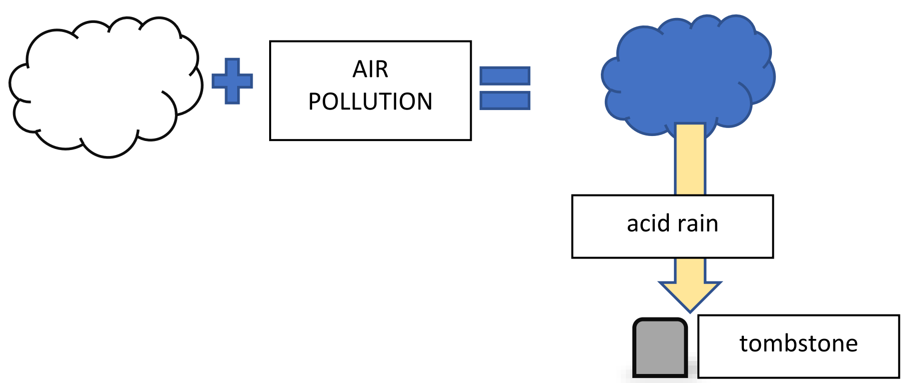
Ask students what they think may be in the water that allows it to dissolve the tombstone. Depending on their background knowledge, you may or may not need to guide them towards the idea of acid in the rain.

TEACHER NOTES

Ask students where the acid in the rain could have come from. Use questions to help them narrow it down (it can't be from the ground – it must be from the air). Key takeaways:

- Air pollution in the atmosphere can dissolve in water in the air and clouds
- The dissolved pollution makes the water acidic
- When it rains, the acid rain can affect things on the ground

5. **Formative assessment:** Have students draw a simple picture showing how air pollution can get into the rain and end up affecting things on the ground. For example:



Name ______________________________

Disappearing Salt

Salt & Water

Observations (ex. color? Solid/liquid/gas? clear/cloudy/opaque? soft or hard?) Salt: Water:	**Observations (ex. color? Solid/liquid/gas? clear/cloudy/opaque? soft or hard?)** Salt + water:
What happened to the salt when you mixed it into the water?	

Soda

Observations (ex. color? Solid/liquid/gas? clear/cloudy/opaque? soft or hard?) Before:	**Observations (ex. color? Solid/liquid/gas? clear/cloudy/opaque? soft or hard?)** After:
What does it mean for something to be dissolved in something else?	

Activity 8 (Explain): Air Pollution in the Chesapeake Bay

ACTIVITY DETAILS

Time: 45 minutes

Objectives

- ✓ Students will be able to describe how air pollution gets into the Chesapeake Bay
- ✓ Students will know the definition of airshed
- ✓ Students will know the term "deposition"

Materials

- ✓ Word wall words: airshed, dry deposition, wet deposition
- ✓ Blank paper
- ✓ Spray bottle(s) with water (one or more)
- ✓ Chocolate pudding mix in small cups
- ✓ Cotton balls
- ✓ Water in small cups

Handouts

- ✓ Welcome to the Airshed

Activity summary: In this activity, students use the definition of a watershed to help them define an airshed – an area of land that shares a common flow of air. They then perform a variation on the crumpled paper watershed activity to show how air pollution, in the form of dry and wet deposition, can get into the Chesapeake Bay.

Standards Connection

DCI: ESS3.C: Human Impacts on Earth Systems

Warmup: What is a watershed? Name two watersheds that you are currently in.

- The purpose of this warmup is to refresh student's memory of the term watershed, which will be important for this activity.
- Students should know that they are in the Chesapeake Bay watershed. If they don't know another watershed they are in, have them consider what large rivers are nearby. They may be in the Potomac River watershed, the Patapsco River watershed, or one of the other major watersheds around the region. To find out exactly what local watershed you are in, go to: https://mywaterway.epa.gov/community and type in your address. The waterway that comes up will be the name of your local watershed.

1. **Frame the activity:** Framing will vary slightly based upon whether you did Activity 7 with students:
   - If you skipped Activity 7: Show students the infographic from Activity 5 again, and remind them that in the last Activity they learned know how pollution from the ground gets into the Bay. But 1/3 of the nitrogen pollution in the Bay comes from the air. How can that happen? Today they are going to answer that question.
   - If you did Activity 7: Remind students that they learned during their last activity how gases can get dissolved into water. Today they're going to apply what they learned to explain how air pollution gets into the Bay.

2. **Where does our air come from?:** Pass out the student handout: "Welcome to the Airshed." Have students look at the map on the left side, and ask them what the gray area is (as a reminder). They may or may not recognize the Chesapeake Bay watershed, so be sure to remind them. Have them write Chesapeake Bay watershed in the space below the map on the left.

TEACHER NOTES

Next have students look at the map on the right. Remind them that they're trying to figure out where the air pollution that ends up in the Chesapeake Bay is coming from. Use questioning to see if they can figure out that the shape on the right represents the area that sends its air to the Chesapeake Bay and so it is called the Chesapeake Bay Airshed (the nitrogen airshed to be specific). Have students write Chesapeake Bay Nitrogen Airshed in the space on the right. Create a joint definition of "airshed" with students to write on their sheets. Airshed definitions can get very technical, but in general, an airshed is an area of land that shares a common flow of air. The Chesapeake Bay Nitrogen airshed defines the area of land that sends air and nitrogen air pollution to the Bay. Add the word airshed to the word wall.

Ask students what they notice about the Chesapeake Bay Nitrogen airshed. Key noticings:

- The airshed is bigger than then watershed (because the air can travel further, and can travel over mountains)
- The airshed include the 7 states from the watershed PLUS 9 more (Michigan, Ohio, Indiana, Kentucky, Tennessee, Georgia, North & South Carolina, and New Jersey)

Tell students that different kinds of pollution have different size airsheds. They are going to focus on the nitrogen airshed, because that is the pollutant they think is causing the algae to grow and kill the fish. Ask students to think about how big the nitrogen airshed for the Chesapeake Bay might be. After giving students a chance to share their ideas, put the actual nitrogen airshed. Have students draw the airshed on their handouts, and compare their guesses with the actual airshed.

3. **Return to the Crumpled Paper watershed**: Pass out plain paper and paper towels to each student. You can have them draw on the paper as before, but it is not necessary for this activity. Have students crumple and uncrumple (but not flatten) the paper just like they did for their watershed simulation in Activity 6. Spray each watershed like before so that the "ground" gets wet and creates small streams and ponds.

Hand out a small cup of chocolate pudding mix and cotton balls to each group of students. Have them stretch out the cotton ball to loosen it up. Tell students that for this activity, the cotton ball will represent clouds and air. The cup of pudding mix will represent a source of air pollution, and the pudding itself is the air pollution.

Have students use the cotton ball to pick up some of the air pollution. Ask students what they think will happen when the "air and clouds" pass over their watershed? (it will drop some of the pollution) Have them shake/tap their cotton balls over the

Defining an airshed

- ✓ Because different air pollutants travel different distances, the airshed changes depending on what pollutant you are talking about. Since this module focuses on nitrogen pollution, students will look at the nitrogen airshed, which includes the airsheds for nitrogen dioxide pollution and ammonia. It is useful to make this clear to students, but don't let it become overly confusing.
- ✓ For another map of the Chesapeake Bay airshed and watershed, go to: https://www.cbf.org/assets/images/misc/the-chesapeakes-airshed.gif This map is slightly different and may represent the airshed for additional pollutants.

TEACHER NOTES

watersheds to see what happens. They should see little specks of "air pollution" sticking to the watershed.

Tell students that this kind of pollution is called "dry deposition." Ask them why they think it's called "dry" (it's because the pollution is dry – it is not dissolved in water). Tell them it is called "deposition" because the pollution is being deposited on the land just like you might make a deposit in the bank. Put "dry deposition" on the word wall and have students add a definition to their notes sheet. Dry deposition is when air pollution falls to earth in solid or gas form.

Ask students if the dry deposition is polluting their water. For the most part, the water should still be clean except if some of the dry deposition fell directly in the water. Spray the watersheds again. Some of the dry deposition should wash into the water. Ask students what happened – just like with the original crumpled paper watershed, much of the pollution got washed into the bigger bodies of water, although some of it sticks.

Pass out the small cups of water to students. Have them dunk their cotton balls in the pudding mix again, then the water. Ask them what they think this represents (a rain cloud that has pollution in it). Students probably know what to do next: squeeze the cloud out over the watershed. Ask them what this represents? (polluted rain/acid rain).

Tell students that this is kind of deposition is called "wet deposition" because it is pollution that is dissolved in water and then "deposited" in the watershed. Put "wet deposition" on the word wall and have students add the definition to their notes sheet. Wet deposition is air pollution that falls to the earth dissolved in water. Acid rain is a form of wet deposition.

Have students look at the water in their crumpled paper watershed. What color is it? (it should be brown). What does this represent? Water that is polluted. How did it get this way? (pollution fell directly in the water, or it washed into the water)

After cleaning up, have students turn to the back side of their papers and jot down some things that they learned from this activity about how air pollution gets into the Chesapeake Bay. When they have had a chance to write, have them discuss with a partner, and then have partners share out to the class. Write down key takeaways on the board or chart paper, and have students add new ideas to their papers. Key takeaways:

- Air pollution can come into the watershed from an area called the airshed, which is bigger than the watershed
- The pollution can fall onto the ground/water as "dry deposition"

Connecting the spheres

- ✓ If you have time, this is another good opportunity to have students explain how the atmosphere is connected to the hydrosphere and the geosphere. The biosphere is connected as well, since much of the acid rain falls on land and is taken up by plants which filter the pollution out.

- The pollution can also mix with water in the atmosphere and fall into the watershed as "wet deposition".
- Dry and wet deposition can fall directly into the water, or it can fall on the ground and be washed into the water.

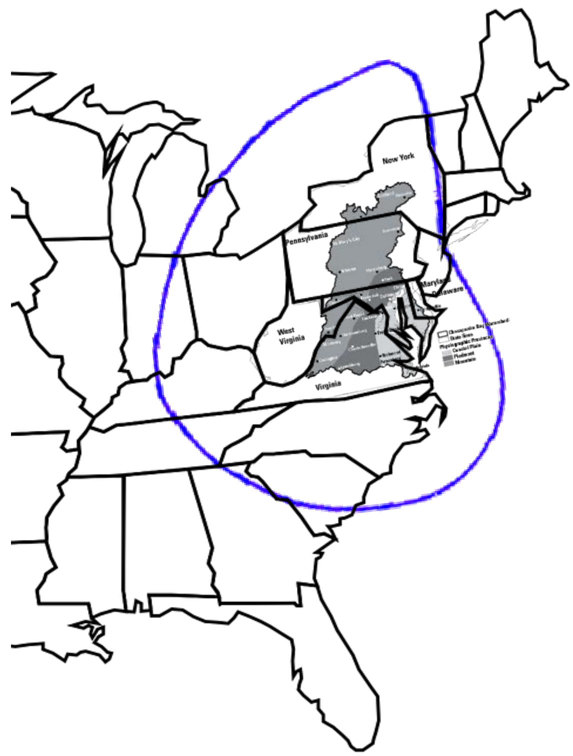
4. **Formative Assessment**: Have students explain in their own words how air pollution from a power plant in Ohio could get all the way into the Chesapeake Bay.
    - Possible answer: The air pollution goes up into the atmosphere, and the pollution mixes with water in a cloud and dissolves. Then the pollution falls onto the Potomac River as rain, and washes into the Chesapeake Bay.

TEACHER NOTES

Name ________________________________

STUDENT HANDOUT

Welcome to the Airshed



____________________________ ____________________________

What is an airshed? ____

____

What is "dry deposition"? ____

____

What is "wet deposition"? ____

____

Conclusions

What did you learn from this activity about how air pollution gets into the Chesapeake Bay?

Activity 9 (Explain): Modeling Pollution in the Chesapeake Bay

ACTIVITY DETAILS

Time: 45 minutes

Objectives

- ✓ Students will begin to create a model of how pollution enters the Chesapeake Bay

Materials

- ✓ Computer & projector
- ✓ Pre-printed/written parts of the Chesapeake Bay pollution model (these can be on paper or on sentence strips) including lots of arrows
- ✓ Extra paper and markers to add components to the model

Handouts

- ✓ none

Activity summary: In this activity, students begin the challenging task of developing a model showing how pollution gets into the Chesapeake Bay. They work collaboratively to come up with a list of what belongs in the model, and then they assemble the model together as a class.

Standards Connection

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
DCI: ESS3.C: Human Impacts on Earth Systems
SEP: Creating & Using Models
CCC: Cause & Effect, Systems and System Models

A Note about timing for this activity

The Chesapeake Bay pollution model can get rather complex. As such, you may want to build it slowly throughout the course of the module as opposed to waiting until this point. Either way, students will need support building the model, so be sure to consider ways to scaffold the model-building however you choose to implement it.

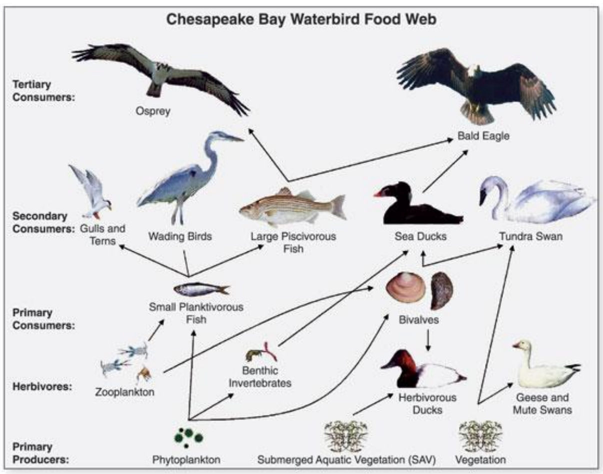
Warmup: Name three ways that nitrogen pollution can get into the Chesapeake Bay.

- Lots of answers are possible: air pollution drifts into the watershed and falls into the water; air pollution falls on the land in the watershed and get washed into the Bay, fertilizer runs off farms into the Bay, etc.

1. **Frame the activity:** Refresh students' memory of how far they've come in investigating what killed the fish in the Chesapeake Bay by reviewing the clues board. They know that the fish died from a lack of dissolved oxygen. They know that this was caused by an algae bloom which was caused by excess nutrients in the Bay. They know that those nutrients came primarily from agriculture and from air pollution. In order to see how all these pieces fit together, marine biologists like themselves would build a model of how pollution gets into the Bay.

   Tell students that modeling is a very important part of the scientific process, especially for scientists who study ecology and ecosystems like the Chesapeake Bay. Today they're going to learn about models and they will create a model together of how pollution affects the Chesapeake Bay. Their model will help them to figure out how to protect the fish and the water.

2. **Food webs as a model**: Display a food web diagram that all students can see, such as the one below. Ask if they have seen anything like this before and what it is. Students may or may not be familiar with food webs, so adjust the time you spend reviewing the food web to make sure all students understand what it shows. Tell students that food webs are one kind of model of an ecosystem. Ask students what they see in the model (arrows, names/pictures of animals, etc.). Tell students that in a food web model, the arrows show how energy moves through an ecosystem. Plants get their energy from the sun so they are at the base of the food web. The arrows show the energy going from the plants, to the animals that eat the plants, and then to animals that eat those animals.



3. **Introducing the components of the Chesapeake Bay pollution model:** Tell students that the model they are building will show how pollution gets into the Bay and affects the living things there. Ask students what things belong in a Chesapeake Bay pollution model. Encourage them to look through their notes from previous activities and at the word wall in the classroom. Possible student responses:
   - The Chesapeake Bay water, dead fish, polluted rain, air pollution, the watershed, the airshed, fertilizer, algae, and wet/dry deposition.

   As students name different things for the model, take out the preprinted sentence strip with each concept/object on it from your pre-printed materials and show it to students. If students name something that you have not premade, write it on a sentence strip or piece of paper and show it to students. Continue adding new components to the model until students' ideas are exhausted. If there are pieces missing, do not worry about introducing them. Students will likely recognize the missing pieces as they are building the model.

TEACHER NOTES

Teacher Tip

✓ The goal of introducing the food web model is not to teach food webs, it is to help students recognize the parts of a model using something that they may already be familiar with. Don't get too hung up on teaching the food web.

Modification

✓ Building the model will likely require a lot of hands-on attention from the teacher, but if you have a large class or you think students will be able to work more independently, consider breaking the class into two or more groups. This has the added benefit of allowing students to see a different version of the model.

TEACHER NOTES

Teacher Tip

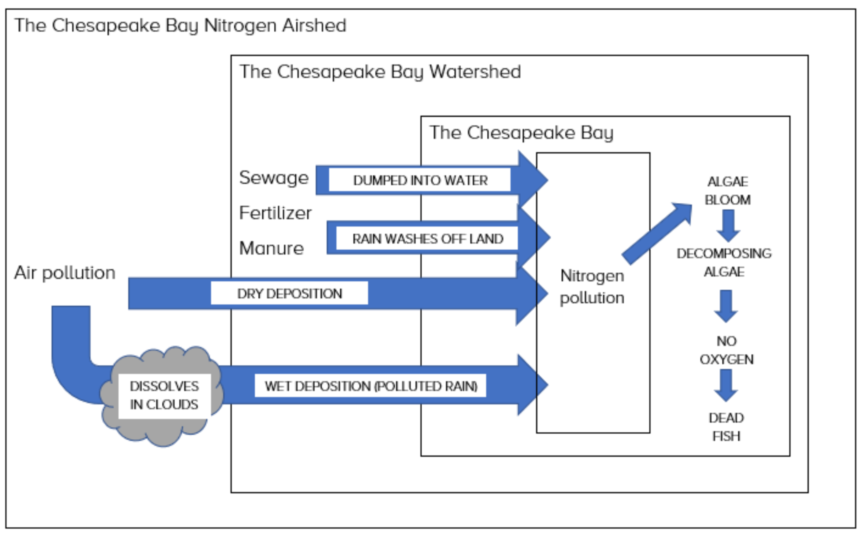
✓ Building the model works best if you can find a large open space in your classroom, or make a space on the floor where all students can see. You can also use a bulletin board and put up the model using push pins. If these types of spaces are not available, consider finding a space to use for the day like the cafeteria (when it is vacant), an outdoor space, or a stage in a school auditorium.

Teacher Tip

✓ Building a complex model like this is bound to be a challenge for middle school students. The key is to go step by step and make little improvements along the way. Use questions to help students make improvements and recognize missing components. Most importantly, let students do the hard work of figuring the model out themselves.

4. **Building the model**: Give one component of the model or arrow to each of the students in the class (depending on the number of students, you may want to have duplicates of some, or you may want to have students work with a partner). Save the dead fish for yourself. Tell students that this investigation started with the dead fish, so you're going to start the model with the dead fish in the Bay. Put the fish in the middle of the space. Tell students that you are going to work backwards from the dead fish all the way back to the air pollution. Ask who has something that connects to the dead fish (dead algae, no oxygen, algae bloom are all good places to start). Have these students add their concepts to the model, using arrows to show how one thing connects to another. Continue building this way, moving backwards. If you hit a point where it makes sense to go in a different direction, then do so. If students have questions or want to move an arrow or an object, that's fine, but have students talk to one another about it (ex. "I think this arrow should go here. Is it okay if I move it?"). If students recognize that something is missing, have additional paper on hand so they can add it to the model.

   A sample model students might come up with could look like this:



   Keep in mind that there is no "perfect" model, but the model should be accurate and make sense.

TEACHER NOTES

5. **Reviewing the model**: Once the model is finished (for now), take time to review parts of the model with students to check for understanding and clear up misconceptions. You may want to attach the model to butcher paper so it can be moved (you can also write additional labels on the butcher paper). Make sure to put the model up in a prominent place for students to use for the remainder of the module. It will be useful to reference the model, and add to or modify it if necessary.

6. **Formative assessment.** Have students reflect on the process of making the model. Here are some sample questions to consider:
   - What did you like about building the model?
   - What was the most challenge part about building the model?
   - If you built another model like this, what would you do differently?

Activity 10 (Explain): What's Going on in our Airshed?

ACTIVITY DETAILS

Time: 45 minutes

Objectives

- ✓ Students will identify major sources of pollution in the airshed

Materials

- ✓ Computer & projector
- ✓ Animated nitrate maps http://nadp.slh.wisc.edu/maplib/ani/no3_conc_ani.pdf
- ✓ Animated ammonium maps http://nadp.slh.wisc.edu/maplib/ani/nh4_conc_ani.pdf
- ✓ Sentence strips for Chesapeake Bay pollution model: nitrate, ammonium, power plants, agriculture, cars, trucks, etc.

Handouts

- ✓ Nitrogen Air Pollution

Map sources

- ✓ The maps for this activity come from the National Atmospheric Deposition Program/ National Trends Network.

Activity summary: In this activity, students learn about the two major forms of nitrogen pollution in the Chesapeake Bay airshed: nitrate and ammonium. They interpret maps to understand how nitrate and ammonium pollution have changed over time, and they read about the two pollutants in order to compare and contrast them. Finally, students add to their Chesapeake Bay Pollution model and identify sources of nitrogen pollution in their communities.

<u>Standards Connection</u>

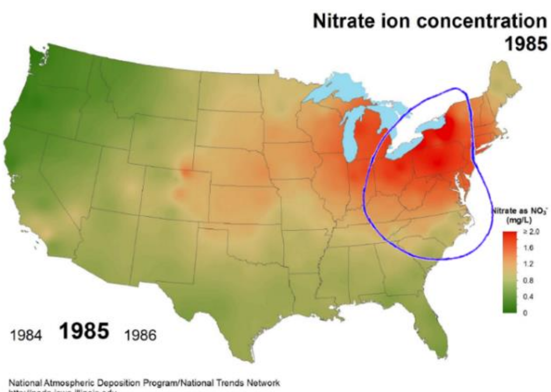
DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
DCI: ESS3.C: Human Impacts on Earth Systems
SEP: Creating & Using Models
CCC: Cause & Effect

Warmup: What kinds of things produce air pollution?

- Possible student responses: cars and trucks, factories, power plants, fires
- If students have completed other modules in On the Air, they will likely be familiar with these answers. If they are new to studying air pollution, they may be less familiar and will need a brief introduction. Either way, the point of this warmup is to focus students' attention on specific sources of air pollution that affect the Chesapeake Bay.

1. **Frame the activity:** Now that we have a model of how pollution can get into the Chesapeake Bay, we need to figure out the actual sources of that pollution if we're going to do something about it. We know that the number one source of pollution is agriculture (farms). The second largest source of pollution to the Bay is air pollution. But where is that air pollution coming from? During our activity today, we'll work on figuring that out.

2. **Nitrate air pollution:** Display the map below so all students can see it.

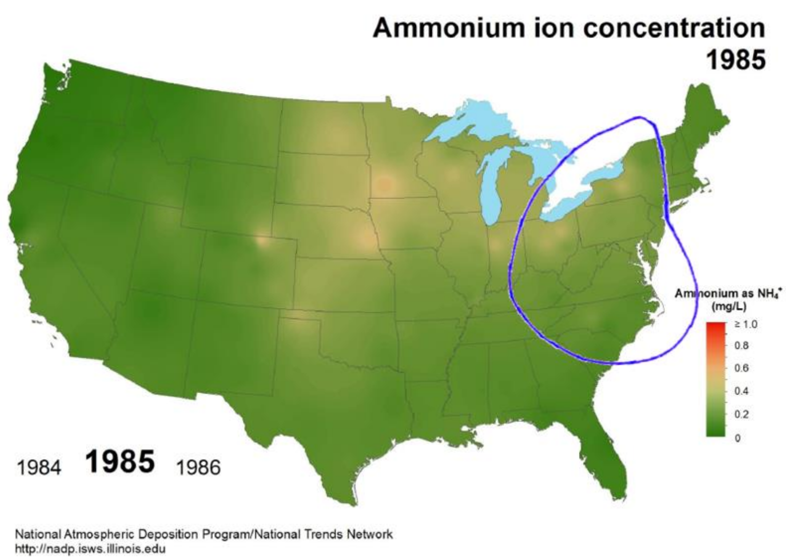


Remind students that the blue shape represents the Chesapeake Bay airshed – the area that shares air with the Chesapeake Bay. Tell them that this map shows one kind of nitrogen pollution in the air called "nitrate". Review the scale of the map with students (red is high, green is low), then ask them what they notice about the map. Key takeaways:

- The nitrate level is very high in the northeast
- The nitrate level is very high in the airshed

Point out to students that this map is from 1985, so the nitrate level was very high then. Tell student that in a few minutes they are going to read about nitrate in more detail.

3. **Ammonium air pollution:** Display the map below so all students can see it:



Tell students that this map shows a different kind of nitrogen pollution in the air called "ammonium". Ask students what they notice about this map. Key takeaways:

- The ammonium level is higher in the middle of the country
- The ammonium level is lower in the Chesapeake Bay airshed.

Based on these two maps, which type of air pollution (nitrate or ammonium) do they think is the bigger problem for the Chesapeake Bay?

- Students will likely say nitrate, although remind them that this isn't the end of the story (it's only 1985).

TEACHER NOTES

Accessibility note

✓ The maps for this activity depend on students seeing different colors. If you have students who are colorblind, they may need assistance in interpreting the maps.

TEACHER NOTES

4. **Nitrate and ammonia air pollution:** Hand out the reading: "Sources of nitrogen air pollution". As students read, they will identify key information about sources of nitrogen pollution, and fill in their Venn diagram.

   After students have finished the reading and filled in their Venn diagrams, lead a discussion to clarify important information.

5. **What's going on with nitrate?** Display the 1985 nitrate map for students to see. Ask them why they think the nitrate pollution was so bad in the Chesapeake Bay airshed in 1985. Use questions and discussion to help them recognize that there were a lot of power plants and a lot of transportation (cars and trucks) in this area at the time. Have students predict what has changed with nitrate since 1985. After they have made their predictions, click through the animated versions of the nitrate maps (download and use the right arrow to advance from map to map): http://nadp.slh.wisc.edu/maplib/ani/no3_conc_ani.pdf

   Were students' predictions right? Ask students why they think the nitrate pollution went down so much. Use questions to help them realize that the power plants we use got cleaner and the most polluting ones closed. Cars also began to pollute less. Nitrate reduction is a success story, but we need to keep moving in the right direction.

6. **What's going on with ammonium?** Display the 1985 ammonium map for students to see. Ask them why they think the ammonium level is worse in the middle of the country compared to the Chesapeake Bay airshed. Use questions and discussion to help them recognize that most of the country's agriculture is in the Midwest. Have students predict what has changed with ammonium since 1985. After they have made their predictions, click through the animated versions of the ammonium maps (download and use the right arrow to advance from map to map): http://nadp.slh.wisc.edu/maplib/ani/nh4_conc_ani.pdf

   Were students' predictions right? Ask students why they think the ammonium pollution went up so much. Use questions to focus on the idea that increased fertilizer use is resulting in increased ammonium air pollution. While this has affected the Chesapeake Bay airshed less than other parts of the country, it is still going up. Right now, the amount of nitrate deposition and ammonium deposition in the Bay is about the same.

7. **Improving our model:** Ask students where nitrate and ammonium belong in their Chesapeake Bay pollution models. Have students add them to their models where appropriate to add detail to "nitrogen air pollution." Also ask about sources of these pollutants. Where can agriculture (fertilizer, manure), power plants, cars & trucks, and any other sources students think are appropriate be added?

8. **Formative assessment**: Ask students what they think is the largest source of nitrogen air pollution in their community? Why do you think so? What kind of air pollution does it produce?
   - Key things to look for: do students correctly match the air pollution to the kind of source, do they choose sources that are prevalent in their communities (ex. cars and trucks most likely, which contribute to the nitrate pollution)

STUDENT HANDOUT

Name ______________________________

Nitrogen Air Pollution

What are nitrate and ammonium?

Nitrate and ammonium are two molecules that are found in air pollution. Both of them contain nitrogen. Nitrate is nitrogen combined with oxygen and has the chemical symbol NO_3^-. Ammonium is nitrogen combined with hydrogen and has the chemical symbol NH_4^+.

Where does nitrate come from?

Nitrate comes from nitrogen dioxide or NO_2, which is a gas that comes from a lot of different sources. NO_2 mainly comes from burning fuel, so sources of NO_2 and nitrate are cars, trucks, power plants, and chemical factories. Nitrate is a main component of acid rain.

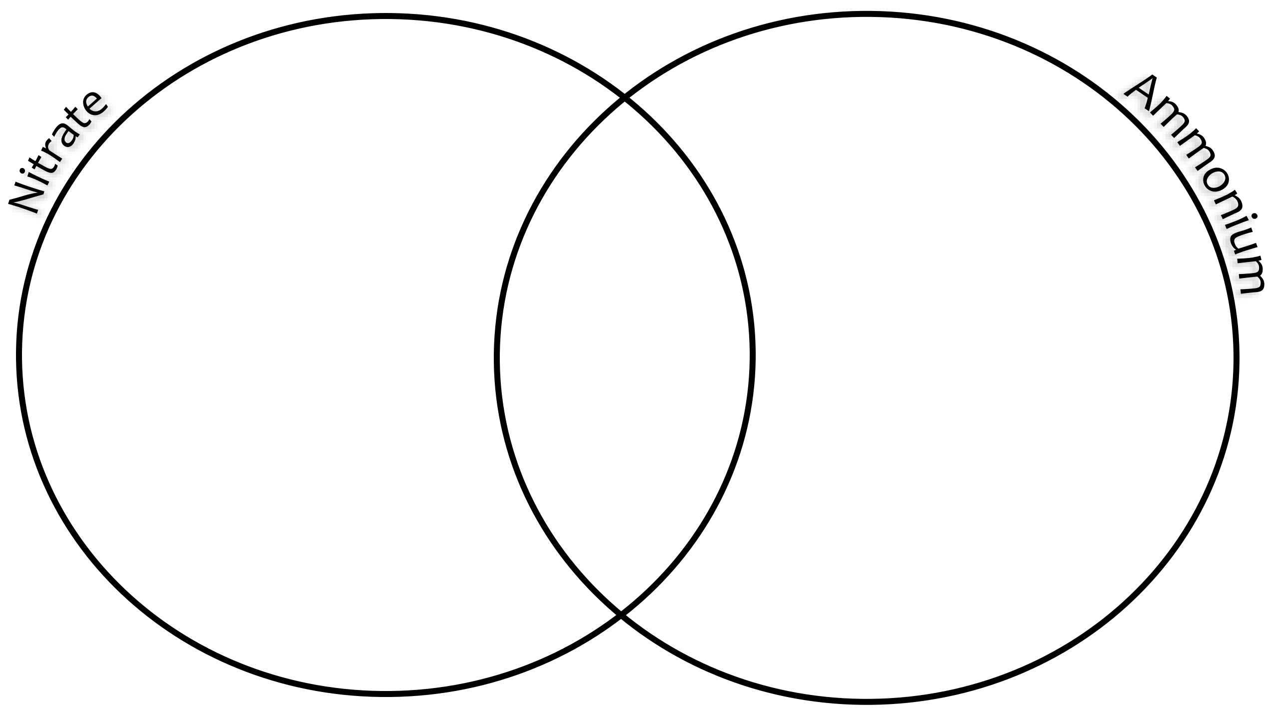
Where does ammonium come from?

Ammonium mainly comes from agricultural sources such as manure and fertilizer. You may have heard of ammonia because it is in some cleaning products. Ammonia and ammonium are very similar molecules.

How do nitrate and ammonium affect the Chesapeake Bay?

When nitrate and ammonium get into the Bay through wet and dry deposition, they can add extra nitrogen to the water. This allows more algae to grow, which can cause dead zones that have little to no dissolved oxygen in them. This can kill animals that need dissolved oxygen to survive.

Fill in the Venn diagram below based upon what you know about nitrate and ammonium.



Activity 11 (Explore): Measuring Wet Deposition of Nitrogen

Activity summary: In this multi-day activity, students collect data to test the accuracy of one portion of their Chesapeake Bay Pollution models. The activity is written for students to collect and analyze rainwater to see if the air has nitrate or ammonium pollution in it. Since MWEEs are designed to be student-driven, this experiment can be modified to test other aspects of their models as well, including water from nearby streams or from the Chesapeake Bay itself.

Standards Connection
DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
DCI: ESS3.C: Human Impacts on Earth Systems
SEP: Planning & Carrying Out Investigations, Creating & Using Models, Constructing Explanations
CCC: Cause & Effect

A note about timing for this activity

This activity requires collecting rainwater from the school grounds. Since precipitation can be an unpredictable occurrence, consider having students make and put out their rainwater collectors as early as possible so that you have rainwater to use. The amount of nitrate and ammonium in the water will decrease if it is not tested soon after the rainfall, but they can be frozen and thawed without significantly affecting the nitrate and ammonium concentrations. Steps 1-4 of the activity introduce the experiment up through making rain gauges, and the remaining steps include water testing, data analysis, and conclusions.

Warmup: How does nitrogen pollution get into rainwater?

- When nitrogen pollution in gas form (NO_x) is released into the atmosphere, it dissolves into the water in clouds and rain.
- This warmup is designed as a reminder to make sure students understand why they are collecting and analyzing rainwater

1. **Frame the activity:** Tell students that when scientists create models to explain something, they also need to test the model to see if it's accurate. While the students cannot test their whole model, they can test part of it to see if what they believe is supported by data. For example, they could test water in local streams to see if it has nitrate in it from wet deposition, or they can test water near farms to see if it has ammonium in it from fertilizer and manure washing off the land. Tell students that there is one type of nitrogen pollution they can test anywhere in the airshed, even if they are not near a stream or a farm. Ask students if they know what kind of pollution they can test for no

ACTIVITY DETAILS

Time: 2-3 class periods

Objectives

- ✓ Students will collect and analyze data to determine if rainwater in the school community is polluted with nitrogen

Materials

- ✓ Nitrate and ammonia test kits (see note on materials)
- ✓ Additional glassware (ex. small beakers) to allow for multiple groups to test at the same time if necessary
- ✓ Rainwater collectors (ex. jars)
- ✓ Distilled water (to use as a control)
- ✓ Safety & cleanup materials (safety goggles, paper towels, etc.)
- ✓ Tips for Measuring Nitrogen Deposition in Rainwater (teacher guide)

Handouts

- ✓ Nitrogen Deposition in Rainwater

TEACHER NOTES

Student Choice

- ✓ MWEEs are designed to promote student choice, especially when it comes to the experimentation, field experiences, and data collection. What is presented here is one option for what students might do to collect data related to air pollution. Others might include collecting water from a local stream and testing for nitrates and ammonium (from runoff pollution), participating in a field experience with a partner organization to collect nitrate data from the Bay, or devising their own method for collecting emissions data from (for example) car exhaust. The important thing is to focus on the type of pollution that is local for students. For many students in the DC-Baltimore area, that pollution is air pollution from transportation.

matter where they are. Use questions to help them realize they can test rainwater to see if the air has nitrogen pollution in it. Ask students if they think the rainwater in their community is polluted. Tell them that they are going to perform the same experiments that scientists do in order to see whether there is wet deposition of nitrogen in their part of the Chesapeake watershed.

A note about materials for this activity

The amount of nitrate and ammonium in rainwater is relatively low, so sensitive tests are required to detect it. There are several companies that produce easy-to-use nitrate and ammonia water tests that are sensitive enough. Kits from CheMetrics are recommended because they are relatively inexpensive and very easy to use. To limit costs, you may consider using one test instead of both. In that case, the Nitrate kit is recommended because it is often present in higher amounts and so will be easier to detect. Refill kits are also less expensive, so if you use the kit in subsequent years, you only need to buy the refills.

- CheMetrics Nitrate test kit: https://www.chemetrics.com/product/nitrate-test-kit-chemets-visual-kit-k-6904/
- CheMetrics Ammonium test kit: https://www.chemetrics.com/product/ammonia-chemets-kit/

Hach also produces similar test kits which are slightly more expensive, but which also have the required sensitivity.

2. **Develop a research question:** Tell students that they will be testing rainwater for nitrate and/or ammonium using a chemical test kit. Before they do that, they need to write a research question based on their model. The research question should ask something about nitrogen pollution in rainwater. Help students to develop a research question related to testing nitrate and/or ammonium levels in rainwater. For example:
   - Does rainwater in our community have higher levels of nitrate than plain water?
   - Is the amount of ammonium in rainwater that falls in our community higher than it plain water?

   Hand out the Nitrogen Deposition in Rainwater sheet to students and have them write down their research question.

3. **Develop a hypothesis**: Ask students what results they expect from their experiment based on their model of Chesapeake Bay pollution. Because students have not discussed actual concentration numbers, their hypotheses can be general (ex. I think that there will not be any nitrate in the rainwater because the air in our community is very clean). Have them write their hypothesis on their handout.

4. **Make rain gauges:** Lead students through the process of creating rain gauges to collect water for their experiment. See the section of the teacher guide under "rainwater collection" for ideas about making and setting up the gauges. When they are ready, set the gauges out around the school grounds (some students may set them up at home) in safe locations.

Continue here after rainwater has been collected and is ready to test

5. **Review testing procedures:** Hand out copies of the nitrate and ammonia testing procedures to students. Review the directions for the procedures, and make sure to discuss with students why they need to test distilled water as well as the rainwater. You may want to complete one test as an example for students or have all students do each step together.

6. **Conduct the tests**: Have students take rainwater (either from their jars, or from rainwater that has been frozen and thawed) and distilled water, and complete the tests to determine the amount of nitrate or ammonium in each sample. Make sure students know where to record their data on their data sheets. Be sure to follow safety procedures and clean-up all materials appropriately.

7. **Pool data**: As students complete their experiments, have them share their data with the rest of the class, either using the board or a computer. Make sure that students record the data in the correct place on their data sheets (ex. nitrate control/experimental; ammonia control/experimental). When they have all the class data, have them calculate averages for each of the tests and write the averages on their data sheets.

8. **Convert units**: Scientists report out the amount of nitrogen in rainwater samples as concentrations of nitrate (ppm NO_3) and ammonium (ppm NH_4). However, most test kits report out on the concentration of nitrogen itself (ppm N-NO_3 and ppm N-NH_4). As such, students need to convert from one unit to the other in order to compare their data with data collected by scientists. The conversion is simple: multiply by 4.43 to convert from ppm N-NO_3 to ppm NO_3 and multiply by 1.29 to convert from ppm N-NH_4 to ppm NH_4. Review this information with students to the degree that they will understand it, and have them complete the conversions on their data sheets.

TEACHER NOTES

Modification

✓ If performing the experiments yourself is not possible due to cost constraints or other circumstances, you can have students review data from the National Atmospheric Deposition Program instead. While this is far from ideal, it will allow students to be able to see what the nitrate and ammonium concentrations are like in the rainwater in their area. See Step 9 for how to access these data.

Control Group

✓ The ideal control group for this experiment would be unpolluted rainwater. However, this is nearly impossible to obtain, so distilled water has been substituted. For information on the composition of unpolluted rainwater, see this website: https://tinyurl.com/cleanrain

TEACHER NOTES

Differentiation

- ✓ If students are new to the CER writing format, consider ways to scaffold the writing prompt. For example, you can have student groups work together to write the CER, or just one part of it. You can also have students write drafts of the reasoning portion, review them together to provide feedback, and have students complete a final draft afterwards.

Modification

- ✓ Because this experiment follows a traditional format, you may want to have students write up their results using a scientific paper format that includes the scientific question, hypothesis, methods, results and conclusion. Middle school students will likely require significant support and scaffolding with this format as it is likely new to them.

9. **Comparing with official data (optional):** Data collection stations around the country follow similar procedures to collect nitrate and ammonium wet deposition data. Go to the National Atmospheric Deposition Program website at http://nadp.slh.wisc.edu/data/ntn/ to find these data. Choose the interactive map option to find the weather station closest to you. Blue pins on the map show active sites. Click on the pin closest to the school to bring up information about that site.

   From the popup menu, click the Data Access link and then the Data tab to see what information is available. Here is a list of commonly available site data:
   - Weekly data (week-by-week deposition data in excel format)
   - Trend plots (graph of average deposition on an annual basis)
   - Annual averages (annual average concentrations in excel format)
   - Precipitation (rainfall timing and amount in excel format)

   The trend plot is easy to read and will allow you to compare your results with annual averages and trends. The weekly data will allow you to see how your data falls into the range of common concentrations. Unfortunately, there is a significant time delay for the national data to be posted, so you cannot get comparison information for recent rainfall events like the one your data come from. Use the link for "metadata" to learn what each of the columns in the spreadsheets represents.

9. **Data analysis:** The data from the rainwater testing will likely be very straightforward since the test kits do not have extremely precise measurements, and student data Is unlikely to have much variation. Unless there is significant variation among student results, students should graph the results of their class averages from each of the tests done (including control groups). Have students write a simple analysis of the data in the space on their data sheets (ex. the difference between the experimental and control group concentrations, and whether it was higher or lower).

10. **Conclusion (Formative assessment):** Have students write a conclusion to their experiment by answering the Claim-Evidence-Reasoning prompt. You may want to discuss conclusions beforehand to help students with their writing. Also consider using one or more of the scaffolding techniques in the differentiation note – or use another technique of your own.

Tips for Measuring Nitrogen Deposition in Rainwater

Rainwater collection

Ideally, students should collect the rainwater for this experiment themselves. To do this, have students make simple rain gauges using a jar or bottle, masking tape, and a ruler to mark off the height on the bottle. You can find many "how to" videos on the internet on how to make simple or more complex rain gauges. Some guides suggest putting water in the bottom of the jar to weight it before setting it out. Be sure that your rain gauge is empty when you set it out because you only want to test rainwater.

Form students into groups, and have each group make a rain gauge with their initials on it. Assign each group a number to write on their gauge as well. When you set out rain gauges, choose a variety of locations, and be sure to mark the gauges as part of an experiment so they are not disturbed. You can also have students set up gauges at their houses. If so, make a plan for students to transport the water to the school by putting a lid or plastic wrap on the tops of the gauges.

Since precipitation is unpredictable, consider collecting rainwater well before you need it. Rainwater should be frozen to prevent any pollutants from evaporating or breaking down before testing. Just thaw the rainwater in advance of testing. If you can be flexible about when to do the test, wait until it rains, then perform the test the next day without freezing the water.

Rainwater testing

You may choose to have all students do both tests (nitrate and ammonia), one test, or split the class so that some groups do one test and other groups do the other. Make sure students know what test(s) they are performing.

Once you have results, use the color scales that come with the kit to have each group determine the concentration of nitrate or ammonium in their water. Make sure each group records their data next to the correct group number of their data sheet.

Converting units

Most chemical tests give results in the amount of nitrogen. To find the concentration of nitrate, you must multiply your results by 4.43. This is because one molecule of nitrate weighs 4.43 times as much as one atom of nitrogen. To find the concentration of ammonium, you need to multiply by 1.29 because one molecule of ammonium weighs 1.29 times as much as one atom of nitrogen.

Name ______________________________

STUDENT HANDOUT

Nitrogen Deposition in Rainwater

Research question: ______________________________

Hypothesis: ______________________________

Height of water in rain gauge: ______________________________

Follow the directions on your test kit to determine the amount of nitrate or ammonium in your rainwater.

Group Number	Nitrate (ppm $N\text{-}NO_3$)		Ammonium (ppm $N\text{-}NH_4$)	
	Rainwater	Control	Rainwater	Control
1				
2				
3				
4				
5				
6				
7				
8				
Class average				

Most chemical tests give results in the amount of nitrogen. To find the concentration of nitrate, you must multiply your results by 4.43. This is because one molecule of nitrate weighs 4.43 times as much as one atom of nitrogen. To find the concentration of ammonium, you need to multiply by 1.29 because one molecule of ammonium weighs 1.29 times as much as one atom of nitrogen.

Nitrate Class Average		Final Nitrate Concentration
Rainwater:	x 4.43	
Control:	x 4.43	

Ammonium Class Average		Final Ammonium Concentration
Rainwater:	x 1.29	
Control:	x 1.29	

Analysis

How does the amount of nitrate in your experimental group (the rainwater) compare the amount of nitrate in your control group?

How does the amount of nitrate in your experimental group (the rainwater) compare the amount of nitrate in your control group?

Do your results support your hypothesis or not?

Conclusion

Write a claim-evidence-reasoning statement that summarizes the results of your experiment. Use the guide below to help you with your statement.

- Your claim should answer your research question and include whether your results support or do not support your hypothesis and your model of pollution in the Chesapeake Bay.
- Your evidence should be a brief summary of the data from your experiment.
- Your reasoning should explain why your data supports your claim. Use what you know about nitrogen air pollution and your Chesapeake Bay Pollution model to explain the connection between nitrates and ammonium in rainwater, air pollution, and pollution in the Chesapeake Bay.

Activity 12 (Elaborate): Doing Our Part

Activity summary: Now that students have learned about sources of nitrogen pollution the Chesapeake Bay, and where it comes from, now is there chance to do something about it! In this multi-day activity, students plan and implement an action project to reduce pollution to the Bay. They will have to make choices about what project to do, and how to do it in order to be successful in doing their part to improve the health of the Bay.

Standards Connection
DCI: ESS3.C: Human Impacts on Earth Systems
CCC: Cause & Effect

A note about student input & planning

Like other components of the MWEE, significant student input should be involved in planning their action project. Because project options are so diverse, the activity guide below can be somewhat vague at times. As always, consider what is best for you and your students, and be creative!

Warmup: What kinds of activities do *you* participate in that result in air pollution going into the Chesapeake Bay airshed? It may be helpful to put up the "sources of nitrogen pollution" graphic to help students complete the warmup.

- Possible answers: using electricity (playing video games, watching tv, surfing the internet, etc.), riding in a car

Gather students' answers, either by having them write their answers on post-its/slips of paper than can be posted, or by writing it on chart paper or a whiteboard so that they can be referenced later.

1. **Frame the activity:** Tell students that now that they understand how much of a problem air pollution can be to the health of the Bay, it's time for them to think about they we can do to help solve the problem. Today they'll start working on an action project to support clean air in the airshed and clean water in the watershed. They will brainstorm different actions we can take, and then we'll decide on a project to do together as a class.

2. **Addressing sources of air pollution**. Go back to the warmup list and have students discuss the ways that they (and the school community) contribute to air pollution. Is there anything missing from the list? Which ones are important to students to address? Which ones are easier for them to address?

ACTIVITY DETAILS

Time: variable depending on action project

Objectives
- ✓ Students will plan and implement an action project to decrease pollution inputs into the Chesapeake Bay

Materials
- ✓ Vary depending upon project chosen

Handouts
- ✓ none

TEACHER NOTES

Teacher tip

- ✓ You may want to jump ahead to the brainstorm activity to before deciding which sources of pollution are easier/harder to address. For example, reducing power plant emissions may seem like a difficult source to address, but in reality, it comes down to using less electricity, which may be easier to do.
- ✓ Remember that it is your role as the teacher to support the student brainstorm, not to make a series of suggestions. If you think students are overlooking a possibility, try asking them some questions to support their thinking rather than just making the suggesting yourself. You want this project to be theirs, not yours.

3. **Brainstorm ways to address these sources.** In groups, have students who are interested in a addressing a particular source work together to brainstorm ways to address that source. If you think students will need more support with this, brainstorm together as a class. Below is a list of suggestions for activities students can take in their school community:

   Transportation emissions:
   - Students create a campaign for a walk/bike to school day once a month/week
   - Students advocate/fundraise for a bike rack for the school
   - Students advocate for a no-idling zone and signs at the school
   - Students create a carpooling program at the school or make plans to carpool with other students
   - Create a transportation log that shows how many miles you ride in a car in a month. Pledge to reduce the number next month.
   - Students create a campaign to support buying locally-sourced food or supporting a local farmers' market

   Electricity usage:
   - Students fundraise to get Kill A Watt electricity use monitors for the school, then use them to monitor and lower electricity use
   - Students create signs around the school reminding teachers and students to shut off lights and electronics when they're not being used
   - Students create pledges for themselves and families to use less electricity at home by turning off lights and electronics, opening windows instead of running the air conditioning, using energy-efficient lighting, etc.

   If you live in a rural community, you can also consider options that support using less fertilizer and or preventing runoff from entering local waterways.

   For additional ideas of what you can do, see EPA's website on nutrient pollution mitigation: https://www.epa.gov/nutrientpollution/what-you-can-do

4. **Choose a class project:** The action project will be more successful if the class undertakes one project together. The same is true if you teach multiple classes. Have students come to a consensus about what project they feel is most important to them. You may want them to discuss/debate ideas, vote on them, etc. as way to reach a decision.

TEACHER NOTES

5. **Plan the project**: With your help, have students divide the project up into smaller pieces that groups of students can work on. For a campaign, some students may make posters, while others write a letter for school staff, administration, or parents. The project may require additional research, so be sure to plan ahead for this. You will likely need to do some planning outside of class, but try to include students in planning as much as possible. Once you have a plan developed, make sure to share that plan with students.

6. **Implement the plan**: Follow your plan, and make adjustments along the way as necessary. You may need to reach out to partners to help support your work with donations or advice. Be sure to document your students' work along the way with pictures, videos, etc.

7. **Celebrate success**: When the project is complete, take time to reflect on and celebrate what you and your students have accomplished. How many pledges have you collected to use less electricity? Have you created a no-idle zone outside the school? Write a story about it for the local newspaper or the school website. Share your success with others in the environmental conservation community.

Activity 13 (Evaluate): Presenting the Chesapeake Bay

ACTIVITY DETAILS

Time: variable depending on presentation format

Objectives

- ✓ Students will use their models and research to create a presentation of the problem of nitrogen pollution in the Chesapeake Bay.

Materials

- ✓ Student Presentation Planning Guide
- ✓ Student presentation look-fors

Handouts

- ✓ Student Presentation Rubric

Activity summary: In this culminating activity, students synthesize what they have learned during the module through their experiments, models, and research. Working together, they develop one or more presentations of their findings to share with stakeholders in the Chesapeake Bay conservation community.

Standards Connection

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
SEP: Obtaining, Evaluating, and Communicating Information
CCC: Cause & Effect

A note about timing

The timing of the last two activities in this module (student presentation and student action project) are completely interchangeable. If you do the action project first, then it is will be easier for students to include "what you can do" suggestions in their presentation. However, sometimes it is easier from a logistical perspective to do the action project last. Choose whichever order works best for you and your students.

A note about student input & planning

Like other components of the MWEE, significant student input should be involved in planning their presentation. They may want to choose the format (poster vs. PowerPoint vs. video), what information is included, and who their audience will be. With this in mind, advance planning is required for the presentation to run smoothly. Try your best to provide as much student input as possible, balanced with the need to anticipate and plan in advance for various components of the project. Use the Planning Guide below to help reach this balance.

Warmup: What are the main sources of nitrogen pollution for the Chesapeake Bay?

- Transportation (cars, trucks, buses), power plants, chemical factories.
- The purpose of this warmup is to remind students where the pollution is coming from that they measured in the rainwater. This is important information for this activity and the action project

1. **Frame the activity:** Use students' clues board and Chesapeake Bay model to remind them how far they've come since they started investigating what happened to the fish in the Chesapeake Bay. Tell them that now it is time for them to present their findings to the community. Over the next few days, they will bring together everything they've learned to create a presentation explaining how nitrogen pollution affects the Chesapeake Bay. The presentation will be based on their model, and it will show all the steps in how nitrogen pollution affects the Bay.

2. **Return to the model**: Before starting to build their presentations, have students look at the model they've created. Discuss whether it is complete or not based on what they've learned. You can have students go back through their activity materials, or you can revisit some of the previous activities to make sure their model has all the important components in it. For example, you may want to label parts of the model that are in the atmosphere, hydrosphere, geosphere, and biosphere. The goal is to both put the finishing touches on the model, and to remind students of important components.

3. **Brainstorming**: Have students consider what important ideas they want to share in their presentation. For example, they should include:
   - The original phenomenon that started their investigation
   - Their "Algae in a Bottle" experiment and results
   - Sources of nitrogen pollution the Chesapeake Bay
   - Their Chesapeake Bay Pollution model
   - Their explanation of the phenomenon
   - Their Action Project
   - What individuals can do to help prevent nitrogen pollution from getting into the Chesapeake Bay

   Also have students consider what format they want to present their work in. They may want to create posters, make videos, make PowerPoint slideshows, or use a completely different format. As the teacher, use the planning guide (below) to set parameters on student options so they can be successful with available resources and time.

4. **Group presentation development:** Divide students into groups, and assign each group their respective roles and responsibilities based upon their choices and your guidelines.

   While students are working on their projects, provide support and feedback however necessary. You may need to teach a mini-lesson on how to use PowerPoint or to create a video using Flipboard. You may need to provide access to resources such as pictures you've taken during the module, images you've shown, or websites you have accessed.

TEACHER NOTES

Audience

✓ Students should have the opportunity to present their findings for an authentic audience. That could be a local environmental group, a community organization, or local elected officials. Consider who could benefit from students' information and ask knowledgeable questions.

TEACHER NOTES

Peer feedback

- ✓ When students are practicing their presentations with peers, have them use the peer feedback form found in the front part of the curriculum.

Students will also need frequent time checks to stay on schedule. If they are working on some of the presentation at home, consider what guidelines and expectations are necessary for this.

Also make sure that students understand how they will be graded on their presentations. A sample generic rubric is below, but it will need to be adapted based on the formats of different student presentations and what content they are expected to include.

6. **Practice:** Once students have finished their presentations, they may need time to rehearse with peers depending on their chosen format. This can be uncomfortable for middle school students, so consider ways to create a safe and calm environment where students can practice and get feedback. For example, have individuals or small groups present to one another instead of the whole class. Having a "glows and grows" feedback form based on the presentation rubric will keep peers active and engaged while their classmates are practicing.

7. **Present!** Have students make their presentations, either by showing videos they've made, explaining posters, leading a slideshow presentation, or doing whatever it is they've chosen. Document the presentations however appropriate. Use your grading rubric and look-fors sheet to assess students' knowledge, understanding, materials, and presentation skills.

8. **Celebrate!** Creating and leading presentations is challenging work. Make sure to celebrate student success in completing the presentation and the MWEE!

TEACHER GUIDE

Student Presentation Planning Guide

This guide is designed to help you answer key questions in planning to support student presentations. Giving students options for their presentations is fantastic. Not putting parameters and limits on those options is a recipe for disaster. Use the questions below to help frame student options and to plan ahead for their needs:

- What presentation formats are available? (ex. video, poster, PowerPoint, etc.)
- Will the class create one presentation together where they all work on different pieces of it, or do you want student groups to create their own presentations? (also, if you teach multiple classes, will each class make their own presentation, or will they all work on different pieces of one presentation?)
- If there will be multiple presentations, do you want each group to use the same format or can they use different formats?
- What materials will be necessary to create the presentation?
- Who will the audience be for the presentation?
- Do students need to learn additional skills to create the presentation (ex. to make a video or a PowerPoint)
- What is the timeline for students to create their presentation?
- Will students be working on their presentation entirely in class, or will they be expected to work on part of it at home?
- How will you grade student presentations? A generic rubric is below, but it will need to be modified based on different formats and expectations.

Student Name ______________________________

Pollution in the Chesapeake Bay Presentation Rubric

Project area	Beginning	Needs Improvement	Proficient	Advanced
Content	Student's presentation has significant factual inaccuracies and shows limited understanding of Chesapeake Bay pollution issues and air pollution in general.	Student's presentation has some factual inaccuracies, and shows some understanding of Chesapeake Bay pollution issues and air pollution in general.	Student's presentation is factually accurate, and shows strong understanding of Chesapeake Bay pollution issues and air pollution in general.	Student's presentation is factually accurate, and shows detailed and extensive understanding of Chesapeake Bay pollution issues and air pollution in general.
Completeness	Student's presentation is missing significant required parts.	Student's presentation addresses most required elements.	Student's presentation addresses all required elements, although some may not be fully complete.	Student's presentation addresses all required elements fully.
Answering questions (if applicable)	Student cannot answer questions about their presentation or answers incorrectly due to gaps in knowledge.	Student can answer some questions about their presentation, but struggles to answer others correctly because of gaps in their knowledge.	Student is able to answer questions about their presentation by drawing upon knowledge from the module, although they may have some gaps in their knowledge.	Student is able to fully answer questions about their presentation by drawing upon knowledge from the module
Craftsmanship	Student's presentation has numerous grammatical errors, and is not delivered smoothly.	Student's presentation has some grammatical errors, and may not be delivered smoothly.	Student's presentation is well-designed, with few grammatical errors. Their presentation may not be delivered smoothly.	Student's presentation is very well designed, with few or no grammatical errors. Their presentation is delivered smoothly and comfortably.

Pollution in the Chesapeake Bay Content Look-Fors

Below are some key ideas to look for in student presentations. This is by no means a comprehensive list, nor should it be considered a checklist for students to complete. Instead, it is a guide of key takeaways from the module that students will likely include in their presentations if they are thorough. It can also serve as a source of questions to students after their presentations to ascertain their understanding. For an excellent example of a short professional presentation that covers many of these topics, check out this video from the Chesapeake Bay Program: https://www.chesapeakebay.net/discover/videos/bay_101_air_pollution

- The Chesapeake Bay watershed is the land around the Bay that drains into the Bay.
- The Chesapeake Bay airshed is the area of land that shares a common flow of air.
- The majority of nitrogen pollution to the Chesapeake Bay comes from somewhere in the airshed.
- Algae blooms are caused when there are too many nutrients in the water
- Dead zones/Fish kills are created after an algae bloom when the algae die and decompose. Decomposers use up the dissolved oxygen, leaving not enough for animals like fish and crabs.
- Nutrient pollution to the Bay (nitrogen and phosphorus) comes mainly from agriculture, but also largely from air pollution
- Pollution that is in the watershed gets washed down to the Bay when it rains
- Air pollution to the Bay falls in the form of dry deposition and wet deposition (dissolved in rain)
- Modeling is a way that scientists can organize what they know about something (like an ecosystem) in order to explain how it works (ex. causes and effects)

Air Quality Champion in Our Commuity

Name: Dr. Lewis Linker
Title: Modeling Coordinator and Team Leader for Science & Analysis
Organization: U.S. Environmental Protection Agency, Chesapeake Bay Program

Photograph courtesy of Chesapeake Quarterly, a magazine from Maryland Sea Grant.
Credit: Michael W. Fincham.

How does your work relate to air quality?
I lead a team that creates models and simulations of the Chesapeake's airshed, watershed, and estuary so decision-makers can make a plan for how to clean up the Chesapeake Bay watershed and tidal waters. The plan is called a Watershed Implementation Plan (WIP) and it's a road map of all the actions we all need to do, from New York to Virginia to get healthy and safe air and waters in the Chesapeake region. Without computer simulations of the airshed and watershed we wouldn't know what a restored Chesapeake looks like or what would be the best way to get there. By problem solving, and communicating, we help decision-makers to deal with challenges like population growth and climate change in the Chesapeake region.

What motivates you to come to work every day?
Restoring the Chesapeake Watershed and Bay is a really, really big deal to me. When I was growing up, the Rouge and Cuyahoga rivers were catching on fire, the Potomac River next to the Nation's Capital stank in the summer heat, and the Chesapeake seemed to be in a death spiral. Now it's all coming back, very slowly, bit-by-bit, but coming back, and it's very satisfying that my Modeling Team has played our very small part in the Chesapeake recovery. Also, I know that my Modeling Team depends on me to do my job and to support them every day, and I depend on them too, so that's a big motivator - being there to support a team with an important mission.

What education and career path did you pursue to have the position that you have today?
My early career path was all over the place! At first, I thought I would go into medicine and I completed a biology and chemistry undergraduate degree at Towson State. Then I became very interested in marine biochemistry research. In the end, I decided that I really wanted to do something that had more promise of immediate, concrete, and significant results that I could point to, so I switched to environmental engineering and I have made that my career ever since. It now sounds all very thought out and methodical, but at the time it really was more of a hot mess! Ultimately though, my broad diversity of technical and scientific training prepared me well for a modeling background. I guess it shows that you never know how it's going to finally turn out. But if you are fortunate enough to really go after learning something that interests you, and if you can find a way for that learning to make a contribution to the general public, then things will turn out alright.

What is your workspace like?
Our Modeling Team works with computer simulations of air and water quality, so really our office can be anywhere! We could work on the far side of the moon as long as we had a good internet connection (and good snacks, of course!). Our Modeling Team runs our experiments and tests just like other scientists, but they are all run in a virtual computer space. In fact, our Airshed Model is simulated in North Carolina, the Watershed Model is done in Annapolis, Maryland, and our Estuary Model was run by in Vicksburg, Mississippi. So our Modeling Team is really all over the place - but not yet on the far side of the moon!

What accomplishment are you most proud of?
When my two boys were very young, they knew my work was to clean up the Bay. So naturally they assumed that once I got to work, I put on an orange jump suit, picked up a bag, and started cleaning up the Chesapeake Bay. Even though my Modeling Team is very accomplished, and have received many awards, I'm most satisfied in being able to join with my Team and with the all of the citizens in the watershed to "pick up a bag" in order to clean up the Chesapeake's airshed and watershed.

Glossary

acid rain - rainfall made sufficiently acidic by air pollution that it causes environmental harm, typically to forests and lakes. The main cause of acid rain is combustion of fossil fuels, which produces waste gases that contain sulfur and nitrogen oxides, which combine with water vapor to form acids. Other forms of acid precipitation are also possible.

airshed – an area of land that shares a common air flow. The Chesapeake Bay nitrogen airshed is the area of land where most of the nitrogen air pollution to the Chesapeake Bay comes from

algae (singular alga) - simple, nonflowering, and typically aquatic organisms of a large group that includes the seaweeds and many single-celled forms. Algae contain chlorophyll but lack true stems, roots, leaves, and vascular tissue

algae bloom - a rapid increase in the population of algae in an aquatic system

ammonium $(NH_4)^+$ – an ion that is related to ammonia (NH_3). Both ammonium and ammonia are common air pollutants that are produced from agriculture and industry.

brackish - slightly salty, like the mixture of river water and seawater in estuaries

dead zone – a low-oxygen, or hypoxic, area of water that can be deadly to aquatic life

decomposer – an organism that breaks down dead or decaying organisms

deposition – the process by which substances are "deposited" on the land or in the water. In the case of air pollution, deposition refers to air pollution from the atmosphere is deposited on land or in the water

dissolve – (as a substance) to become incorporated into another substance so as to form a solution. Most commonly, when a solid or gas is dissolved into a liquid

dissolved oxygen - oxygen molecules that are dissolved in and which is available to living aquatic organisms.

dry deposition – the process by which air pollution is deposited directly from the atmosphere, either as a gas or a solid

ecosystem - a biological community of interacting organisms and their physical environment

estuary - a partially enclosed, coastal water body where freshwater from rivers and streams mixes with salt water from the ocean. Estuaries, and their surrounding lands, are places of transition from land to sea.

eutrophication – an excessive amount of nutrients in a lake or other body of water, frequently due to runoff from the land, which causes a dense growth of plant life and may cause the death of animal life from lack of oxygen.

fish kill - the sudden and unexpected death of a number of fish or other aquatic animals such as crabs or prawns over a short period of time and often within a particular area in the wild.

food web – a model showing how energy and matter are transferred in an ecosystem by indicating what organisms eat or are decomposed by other organisms

geosphere – the solid components of Earth in comparison to the hydrosphere, atmosphere, and biosphere.

hydrosphere - all the waters on or below the earth's surface, such as aquifers, lakes, and seas. Sometimes hydrosphere is also used to refer to water vapor in the form of clouds.

menhaden – a common fish found in the Chesapeake Bay. Also known as mossbunker and bunker

MWEE (Meaningful Watershed Educational Experience) - an investigative or experimental project that engages students in thinking critically about the Chesapeake Bay watershed

nitrate $(NO_3)^-$ – an ion that is a common component of fertilizers. Nitrate often forms when nitrogen dioxide (an air pollution) reacts with other pollutants and dissolves in water vapor. Nitrate is common component of nutrient pollution.

nitrogen – an element found abundantly in the Earth's atmosphere. When combined with oxygen, nitrogen forms nitrogen oxides (NO_x), a common form of air pollution and a contributor to nutrient pollution

nitrogen dioxide (NO_2) – a highly reactive gas that is a common air pollutant. Nitrogen dioxide primarily comes from burning fossil fuels in power plants, cars, trucks, and other vehicles.

nutrient pollution - is the process where too many nutrients, mainly nitrogen and phosphorus, are added to bodies of water and can act like fertilizer, causing excessive growth of algae.

phosphate $(PO_4)^3$ – an ion that is a common component of fertilizers. Phosphate is a common component of nutrient pollution.

phosphorus – n metallic element that commonly combines with oxygen to form the phosphate ion. In this form, phosphorus is a common contributor to nutrient pollution

rain gauge - a device for collecting and measuring the amount of rain which falls

watershed – an area of land that drains into a specific body of water

wet deposition – the process by which air pollution is deposited by mixing with precipitation

MODULE 5

Air & Climate Change

Rising Temperatures, Rising Tides

Module Overview

In 2006, former Vice President Al Gore went on tour with the new film “An Inconvenient Truth” to educate Americans about the dangers of climate change. Since then, people in this country and around the world have awakened to the new reality of a warming planet and all the consequences that go with it. In this module, students use the phenomenon of rising sea levels and “sunny day flooding” to investigate the causes and effects of climate change including melting polar ice, the greenhouse effect, atmospheric carbon dioxide levels, and burning fossil fuels. By the end of the unit, students will have developed a cause and effect chain that leads from power plants to flooded coastlines. They will also learn how they can fight climate change through individual action, group effort, and building climate resilience into their communities.

Anchor phenomenon: A city that is flooding on a sunny day.

Pacing

- 8 activities (+2 optional) and summative assessment
- Approximately 11-13 class periods + summative assessment

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When to Teach This Module

Finding the right place within a science scope and sequence to investigate air pollution with students can be tricky. Below you will find some information about the module that can help you decide where this it might fit into your own plans for student leaning:

- **Connection to Ecology:** Studying climate change fits well within a life science course during a unit on ecology. If you are studying ecosystems – and in particular the carbon cycle – teaching this module afterwards to see how ecosystems are affected by climate change is a natural progression. It will also allow students to dive more deeply into human impacts on ecosystems and the planet.

- **Connection to Natural Resource Usage:** If you are teaching an earth science unit on natural resource use, this module would fit well afterwards as a way to investigate the environmental consquences of using certain kinds of natural resources such as fossil fuels. Students may not make that connection until later in the unit, but the anchor phenomenon will set the stage well for students to have the eventual aha! realization of how natural resources and global climate are inextricably intertwined.

Standards Overview

Middle School NGSS standards alignment:

Performance Expectations

Focus PE:

MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. [Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.]

Background PE:

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.* [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).]

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]

Science & Engineering Practices

Focus SEP: Analyzing data
Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.
- Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
- Distinguish between causal and correlational relationships in data.
- Analyze and interpret to provide evidence for phenomena.
- Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).

Background SEP: Planning and carrying out investigations
Planning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions.

- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
- Evaluate the accuracy of various methods for collecting data.
- Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.

Background SEP: Asking questions and defining problems
Asking questions and defining problems in 6–8 builds on K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models. Ask questions…

- that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
- to determine relationships between independent and dependent variables and relationships in models.
- to clarify and/or refine a model, an explanation, or an engineering problem.
- that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.

Background SEP: **Using mathematics and computational thinking**
Using mathematics and computational thinking in 6–8 builds on K–5 experiences and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.

- Use mathematical representations to describe and/or support scientific conclusions and design solutions.
- Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.

Disciplinary Core Ideas

Focus DCI: ESS3.D: Global Climate Change
Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

Background DCI: ESS3.C: Human Impacts on Earth Systems
Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

Crosscutting Concepts

Focus CCC: Cause and Effect: Mechanism and Prediction – Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

- Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.
- Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability

Background CCC: Patterns – Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

- Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems.
- Patterns can be used to identify cause and effect relationships.
- Graphs, charts, and images can be used to identify patterns in data.

Connections to Engineering, Technology, and Applications of Science
Influence of Science, Engineering, and Technology on Society and the Natural World

All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.

NGSS 5th Grade Standards alignment

Performance Expectations:

Focus SEP:
5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

Background SEP:
5-ESS2-1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. [Clarification Statement: Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere. The geosphere, hydrosphere, atmosphere, and biosphere are each a system.] [Assessment Boundary: Assessment is limited to the interactions of two systems at a time.]

Science & Engineering Practices

Focus SEP: Analyzing Data
Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used.

- Represent data in tables and/or various graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships.
- Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.
- Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.
- Analyze data to refine a problem statement or the design of a proposed object, tool, or process.

Background SEP: Planning and carrying out investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.
- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.

Background SEP: Asking questions and defining problems
Asking questions and defining problems in 3–5 builds on K–2 experiences and progresses to specifying qualitative relationships.

- Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.

Background SEP: Using mathematics and computational thinking
Mathematical and computational thinking in 3–5 builds on K–2 experiences and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions.

- Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address scientific and engineering questions and problems.

Disciplinary Core Ideas

Focus DCI: ESS3.C: Human Impacts on Earth Systems
Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.

Background DCI: ESS2.A: Earth Materials and Systems
Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean
supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather.

Crosscutting Concepts

Focus CCC: Cause and Effect: Mechanism and Prediction – Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

- Cause and effect relationships are routinely identified, tested, and used to explain change.
- Events that occur together with regularity might or might not be a cause and effect relationship.

Background CCC: **Patterns** – Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

- Patterns of change can be used to make predictions.
- Patterns can be used as evidence to support an explanation.

Connections to Engineering, Technology, and Applications of Science
Influence of Science, Engineering, and Technology on Society and the Natural World

All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.

The uses of technologies and limitations on their use are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.

Virginia Standards of Learning (SOLs) alignment

Science & Engineering Practices	
Earth Science ES.1 (a)	Asking questions and defining problems. The student will... • ask questions that arise from careful observation of phenomena, examination of a model or theory, or unexpected results, and/or to seek additional information • generate hypotheses based on research and scientific principles • make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated
Earth Science ES.1 (b)	Planning and carrying out investigations. The student will… • individually and collaboratively plan and conduct observational and experimental investigations • select and use appropriate tools and technology to collect, record, analyze, and evaluate data
Earth Science ES.1 (c)	Interpreting, analyzing, and evaluating data. The student will… • construct and interpret data tables showing independent and dependent variables, repeated trials, and means • construct, analyze, and interpret graphical displays of data and consider limitations of data analysis • apply mathematical concepts and processes to scientific questions • use data in building and revising models, supporting explanations of phenomena, or testing solutions to problems • analyze data using tools, technologies, and/or models in order to make valid and reliable scientific claims or determine an optimal design solution
Content Standards	
Earth Science ES.6	The student will investigate and understand that resource use is complex. Key ideas include… a) global resource use has environmental liabilities and benefits
Earth Science ES.11	The student will investigate and understand that the atmosphere is a complex, dynamic system and is subject to long-and short-term variations. Key ideas include… c) natural events and human actions may stress atmospheric regulation mechanisms; and d) human actions, including economic and policy decisions, affect the atmosphere.
Earth Science ES.12	The student will investigate and understand that Earth's weather and climate are the result of the interaction of the sun's energy with the atmosphere, oceans, and the land. Key ideas include… e) changes in the atmosphere and the oceans due to natural and human activity affect global climate.

Common Core State Standards alignment

Literacy Standards	
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
RST.6-8.4	Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.
RST.6-8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
WHST.6-8.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
SL.8.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.
Math Standards	
MP.1	Make sense of problems and persevere in solving them.
MP.2	Reason abstractly and quantitatively.
6.RP.A.3	Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations.
6.RP.A.1	Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.
7.EE.B.3	Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.
7.RP.A.3	Use proportional relationships to solve multistep ratio and percent problems. Examples: simple interest, tax, markups and markdowns, gratuities and commissions, fees, percent increase and decrease, percent error.

5E Module Flow

Activity 1 (Engage): Under Water
Timing: 45 minutes
Purpose: Introducing the anchor phenomenon and developing questions and methods to investigate them
- ✓ Students will make observations and ask questions to better understand the phenomenon of "sunny day flooding"
- ✓ Students will generate ideas for how to answer their questions about the phenomenon

Activity 2 (Explore): Where Does Sunny Day Flooding Happen?
Timing: 45-60 minutes
Purpose: Making a cause-effect connection between sunny day flooding and sea level rise in coastal communities
- ✓ Students will use maps to determine the location of sunny day floods in order to investigate the cause of the phenomenon.
- ✓ Students will understand how sea level rise affects coastal communities

Activity 3 (Explore): Why Are Sea Levels Rising?
Timing: 1-2 class periods
Purpose: Planning and conducting experiments to show a cause-effect connection between sea level rise and melting land ice
- ✓ Students will design and conduct experiments to determine the effect of melting land and sea ice on sea level change.

Activity 4 (Explain): Rising Temperatures, Rising Tides
Timing: 60 minutes
Purpose: Connecting global temperature increases to rising carbon dioxide levels and the greenhouse effect.
- ✓ Students will analyze graphs to identify the correlation between carbon dioxide concentrations in the atmosphere and global temperature increases
- ✓ Students will be able to explain the greenhouse effect in order to show how carbon dioxide is causing global temperature increases

Activity 5 (Explore/Explain): The Greenhouse Effect & Urban Heat Islands (optional)
Timing: 1-2 class periods
Purpose: Demonstrating how the greenhouse effect and urban heat islands work
- ✓ Students will perform experiments to simulate how the greenhouse effect works
- ✓ Students will perform experiments to explain one cause of the urban heat island effect

Activity 6 (Explore): Atmosphere in a Jar
Timing: 45-60 minutes
Purpose: Understanding the composition of Earth's atmosphere
- ✓ Students will know what gases make up Earth's atmosphere and in what proportions
- ✓ Students will use sampling and quantitative analysis to estimate the composition of a mixture

Activity 7 (Elaborate): How Must is a PPM? (optional)
Timing: 30-45 minutes
Purpose: Building understanding of the unit "part-per-million"
- ✓ Students will develop an intuitive and mathematical sense of the unit parts-per-million
- ✓ Students will understand that very small amounts of pollution can have a big effect on the atmosphere

Activity 8 (Elaborate): Climate Change and Resilience
Timing: 45-60 minutes
Purpose: Understanding the effects of rising global temperatures (climate change) and what communities can do to protect themselves from these effects
- ✓ Students will understand the concept of climate change and how it is tied to atmospheric CO_2 concentration
- ✓ Students will understand the concept of climate resilience and how it applies to sea level rise

Activity 9 (Elaborate): CO_2 Sources & Solutions
Timing: 45 minutes
Purpose: Understanding the where greenhouse gases come from and how to minimize those sources
- ✓ Students will understand where fossil fuels come from
- ✓ Students will understand how carbon dioxide gets into the atmosphere from fossil fuels
- ✓ Students will identify local sources of greenhouse gas emissions
- ✓ Students will brainstorm ideas for keeping carbon dioxide out of the atmosphere

Activity 10 (Elaborate): Doing Our Part
Timing: 2 or more class periods
Purpose: Provoding an opportunity to students to take an active role in preventing climate change through both individual and group efforts
- ✓ Students will use what they have learned in the module to create individual and group action plans to address climate change.
- ✓ Students will advocate for climate change in their communities by completing a group action project.

Activity 11 (Evaluate): Earth in 2050
Timing: 30 minutes
Purpose: Assessing students' mastery of key module learning objectives and skills
- ✓ Students will demonstrate their understanding of key climate change ideas related to greenhouse gases, sea level rise, and climate resilience.
- ✓ Students will interpret graphs to draw conclusions about climate change scenarios

Module Materials

Activity 1 (Engage): Under Water

- ❒ Handouts: Phenomenon I See I Wonder
- ❒ Materials needed: Computer & projector, Sticky notes (enough for all students to have a few)
- ❒ Optional materials: Plain paper, Air Quality Champion interview (optional) – see end of module

Activity 2 (Explore): Where Does Sunny Day Flooding Happen?

- ❒ Handouts: Sunny Day Floods
- ❒ Materials needed: Computer & projector
- ❒ Optional materials: Student computers (highly recommended)

Activity 3 (Explore): Why Are Sea Levels Rising?

- ❒ Handouts: What is Causing the Ocean to Rise?
- ❒ Materials needed: Computer & projector, Ice, Water, Measuring cups, Containers, Rulers, Clay or other materials to make "land" (see activity for details on these materials)
- ❒ Optional materials: Scale (optional to weigh ice), Heat lamp

Activity 4 (Explain): Rising Temperatures, Rising Tides

- ❒ Handouts: Rising Temperatures, Rising Tides
- ❒ Materials needed: Computer & Projector, Speakers for video
- ❒ Optional materials: None

Activity 5 (Explore/Explain): The Greenhouse Effect & Urban Heat Islands

- ❒ Handouts: The Greenhouse Effect and Urban Heat Islands
- ❒ Materials needed: Computer & projector, Glass jars with a whole punched in the lid for a thermometer, Thermometers, Black and white construction paper, Other "surface" materials: soil, grass, rocks, sticks, sand, roof shingle, water, etc., Stopwatch (at least one),
- ❒ Optional materials: Clipboards (for recording data outside), Graph paper

Activity 6 (Explore): Atmosphere in a Jar

- ❒ Handouts: Atmosphere in a Jar activity sheet, Atmosphere in a Jar summary questions (optional)
- ❒ Materials needed: Computer & projector, One apple (any kind), Beans for Atmosphere in a Jar (see teacher handout), One large clear container, Small cups – enough for one per student group, Calculators,
- ❒ Optional materials: Apple peeler, Chart paper & markers

Activity 7 (Elaborate): How Much is a PPM? (optional)
- ❒ Handouts: How Much is a PPM?
- ❒ Materials needed: Atmosphere in a Jar (from previous activity)
- ❒ Optional materials: none

Activity 8 (Elaborate): Climate Change & Resilience
- ❒ Handouts: What is Climate Change?, Climate Resilience and Sea Level Rise
- ❒ Materials needed: Computer & Projector, Speakers (for video)
- ❒ Optional materials: none

Activity 9 (Elaborate): CO_2 Sources & Solutions
- ❒ Handouts: Carbon dioxide and Fossil Fuels graphic organizer
- ❒ Materials needed: Computer & projector, Speakers (for video), Plain paper
- ❒ Optional materials: Student computers

Activity 10 (Elaborate): Doing Our Part
- ❒ Handouts: My carbon footprint, What I Can Do, What We Can Do
- ❒ Materials needed: Computer & projector, Speakers (for video and podcast), Make A Pledge!
- ❒ Optional materials: Student computers

Activity 11 (Evaluate): Earth in 2050
- ❒ Handouts: Earth in 2050 assessment
- ❒ Materials needed: Computer & projector
- ❒ Optional materials: none

Teacher Background Information

Climate Change Basics

Observations across the United States and world provide multiple, independent lines of evidence that climate change is happening now.

Our Earth is warming. Earth's average temperature has risen by 1.5°F over the past century, and is projected to rise another 0.5 to 8.6°F over the next hundred years. Small changes in the average temperature of the planet can translate to large and potentially dangerous shifts in climate and weather.

The evidence is clear. Rising global temperatures have been accompanied by changes in weather and climate. Many places have seen changes in rainfall, resulting in more floods, droughts, or intense rain, as well as more frequent and severe heat waves.

The planet's oceans and glaciers have also experienced some big changes – oceans are warming and becoming more acidic, ice caps are melting, and sea levels are rising. As these and other changes become more pronounced in the coming decades, they will likely present challenges to our society and our environment.

What is the difference between climate change and global warming?

Global warming refers to the recent and ongoing rise in global average temperature near Earth's surface. It is caused mostly by increasing concentrations of greenhouse gases in the atmosphere. Global warming is causing climate patterns to change. However, global warming itself represents only one aspect of climate change.

Climate change refers to any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among other effects, that occur over several decades or longer.

Humans are largely responsible for recent climate change

Over the past century, human activities have released large amounts of carbon dioxide and other greenhouse gases into the atmosphere. The majority of greenhouse gases come from burning fossil fuels to produce energy, although deforestation, industrial processes, and some agricultural practices also emit gases into the atmosphere.

Greenhouse gases act like a blanket around Earth, trapping energy in the atmosphere and causing it to warm. This phenomenon is called the greenhouse effect and is natural and necessary to support life on Earth. However, the buildup of greenhouse gases can change Earth's climate and result in dangerous effects to human health and welfare and to ecosystems.

Climate change affects everyone

Our lives are connected to the climate. Human societies have adapted to the relatively stable climate we have enjoyed since the last ice age which ended several thousand years ago. A warming climate will bring changes that can affect our water supplies, agriculture, power and transportation systems, the natural environment, and even our own health and safety.

Some changes to the climate are unavoidable. Carbon dioxide can stay in the atmosphere for nearly a century, so Earth will continue to warm in the coming decades. The warmer it gets, the greater the risk for more severe changes to the climate and Earth's system. Although it's difficult to predict the exact impacts of climate change, what's clear is that the climate we are accustomed to is no longer a reliable guide for what to expect in the future.

We can reduce the risks we will face from climate change. By making choices that reduce greenhouse gas pollution, and preparing for the changes that are already underway, we can reduce risks from climate change. Our decisions today will shape the world our children and grandchildren will live in.

You can take action. You can take steps at home, on the road, and in your office to reduce greenhouse gas emissions and the risks associated with climate change. Many of these steps can save you money; some, such as walking or biking to work, can even improve your health! You can also get involved on a local or state level to support energy efficiency, clean energy programs, or other climate programs.

Source: Climate Change Basic Information. US EPA
https://19january2017snapshot.epa.gov/climatechange/climate-change-basic-information_.html

Additional Climate Change Resources

There are many, many resources available online to provide deeper understanding of climate change, including several great videos. Because climate change can be a controversial topic, make sure to get additional information from reputable sources.

Here are a few additional resources to check out:

- **Global Climate Change: Vital Signs of the Planet.** This is an excellent website from NASA that includes up-to-date data, evidence, news, interactive simulations, and more about climate Change: https://climate.nasa.gov/

- **Climate Change Basics**. This is a short, but useful video about climate change from the US EPA: https://www.youtube.com/watch?v=ScX29WBJI3w#at%3D81

- **NOAA's Climate Portal:** This website isn't as fancy as NASA's, but it has a lot of data, teaching resources, images, and other information about climate change. Also, it's an easy address to remember: https://climate.gov/

Is Sea Level Rising?

Yes, sea level is rising at an increasing rate

Global sea level has been rising over the past century, and the rate has increased in recent decades. In 2014, global sea level was 2.6 inches above the 1993 average—the highest annual average in the satellite record (1993-present). Sea level continues to rise at a rate of about one-eighth of an inch per year.

Higher sea levels mean that deadly and destructive storm surges push farther inland than they once did, which also means more frequent nuisance flooding. Disruptive and expensive, nuisance flooding is estimated to be from 300 percent to 900 percent more frequent within U.S. coastal communities than it was just 50 years ago.

The two major causes of global sea level rise are thermal expansion caused by warming of the ocean (since water expands as it warms) and increased melting of land-based ice, such as glaciers and ice sheets. The oceans are absorbing more than 90 percent of the increased atmospheric heat associated with emissions from human activity.

With continued ocean and atmospheric warming, sea levels will likely rise for many centuries at rates higher than that of the current century. In the United States, almost 40 percent of the population lives in relatively high-population-density coastal areas, where sea level plays a role in flooding, shoreline erosion, and hazards from storms. Globally, eight of the world's 10 largest cities are near a coast, according to the U.N. Atlas of the Oceans.

What's the difference between global and local sea level?

Global sea level trends and relative sea level trends are different measurements. Just as the surface of the Earth is not flat, the surface of the ocean is also not flat—in other words, the sea surface is not changing at the same rate globally. Sea level rise at specific locations may be more or less than the global average due to many local factors: subsidence, upstream flood control, erosion, regional ocean currents, variations in land height, and whether the land is still rebounding from the compressive weight of Ice Age glaciers.

Sea level is primarily measured using tide stations and satellite laser altimeters. Tide stations around the globe tell us what is happening at a local level—the height of the water as measured along the coast relative to a specific point on land. Satellite measurements provide us with the average height of the entire ocean. Taken together, these tools tell us how our ocean sea levels are changing over time.

Sea level rise at specific locations may be more or less than the global average due to local factors such as land subsidence from natural processes and withdrawal of groundwater and fossil fuels, changes in regional ocean currents, and whether the land is still rebounding from the compressive weight of Ice Age glaciers. In urban settings, rising seas threaten infrastructure necessary for local jobs and regional industries. Roads, bridges, subways, water supplies, oil and gas wells, power plants, sewage treatment plants, landfills—virtually all human infrastructure—is at risk from sea level rise.

Source: Is sea level rising? National Ocean Service, National Oceanic and Atmospheric Administration: https://oceanservice.noaa.gov/facts/sealevel.html

Additional Resources

- **Sea-level rise projections for Maryland 2018.** This is a very informative and detailed report from the University of Maryland Center for Environmental Science (UMCES) about how sea-level is expected to rise in Maryland https://www.umces.edu/sea-level-rise-projections

- **Climate Resilience Portal.** This website is a great primer on climate resilience from the Center for Climate and Energy Solutions. As we work to help students develop proactive attitudes about addressing climate change, climate resilience is an important concept for them to understand: https://www.c2es.org/content/climate-resilience-overview/

- **Baltimore Climate Action Plan.** Baltimore's Climate Action plan has been lauded for its inclusive approach of working directly with residents to build a plant to tackle climate change. The plan is extensive, but you can also read a summary on their webpage, and also check out a cute animated video that goes with it here: https://www.baltimoresustainability.org/plans/climate-action-plan/

Quantities and units used in this module

Air pollutants, including carbon dioxide, may be harmful at very small amounts. To describe these very small amounts of gases, scientists use the measures parts per million (ppm) and parts per billion (ppb). One percent is equal to one part per hundred or 10,000 parts per million. Similarly, one part per million equals 0.0001%.

$$1\% = \frac{1}{100} \times \frac{10{,}000}{10{,}000} = \frac{10{,}000}{1{,}000{,}000}$$

1% = 10,000 ppm

$$\frac{1}{1{,}000{,}000} \times \frac{0.0001}{0.0001} = \frac{0.0001}{100} = 0.0001\%$$

1 ppm = 0.0001%

Expressed using ppm, the major components of Earth's atmosphere are:

- Nitrogen: 780,800 ppm (78.08%)
- Oxygen: 209,500 ppm (20.95%)
- Argon: 9,340 ppm (0.93%)
- Water vapor: ~10,000 ppm (~1%)
- Carbon dioxide: 410 ppm (0.041%)

Activity 1 (Engage): Under Water

ACTIVITY DETAILS

Time: 45 minutes

Objectives
- ✓ Students will make observations and ask questions to better understand the phenomenon of "sunny day flooding"
- ✓ Students will generate ideas for how to answer their questions about the phenomenon

Materials
- ✓ Sticky notes (enough for all students to have a few)
- ✓ Plain paper (optional)

Handouts
- ✓ Phenomenon I See I Wonder
- ✓ Air Quality Champion interview (optional) – see end of module

Alternative media
- ✓ Instead of showing students the pictures, you can show them this video without sound from 0:32 to 1:20: https://youtu.be/h-BSJXMkeqg
- ✓ Leaving the sound off will prevent "giving away" the explanation of the phenomenon.

Activity summary: In this introductory activity, students look at pictures or watch a video of "sunny day flooding" which occurs due to high tides and rising sea level as opposed to rainfall. From these images, they generate and organize questions for their new investigation, and brainstorm ways that they can answer those questions.

Standards Connection

DCI: ESS3.C: Human Impacts on Earth Systems
SEP: Asking Questions and Defining Problems
CCC: Cause & Effect

Warmup: Have you ever had a flood in your neighborhood or home? What was the weather like before and during the flood?

- The purpose of this warmup is for students to make a connection with flooding, and to setup a contrast between flooding they are likely used to (during/after a storm) and flooding due to sea-level rise.

1. **Frame the activity:** Tell students that today they are starting a new investigation. For this investigation they are going to be looking at a major global phenomenon from the perspectives of many different people: including scientists, business owners, and themselves.

2. **Introduce the Phenomenon:** Pass out the Phenomenon I See I Wonder handout to students. Then show them pictures of sunny-day flooding (flooding that occurs without a storm), or put up pictures and have them do a gallery walk. Have students write down what they see and what they wonder about the pictures. Sample pictures:

Once students have had a chance to look at all the pictures, have them what they notice. Possible answers:

- It's not raining in any of these pictures
- The sky is blue in some of the pictures
- The water level is high

Tell students that this type of flood has a special name called, a "sunny day flood." Ask students why they think it's called a sunny day flood (because the flood happens when there's no rain).

3. **Generating questions:** Make sure students have written down some wonderings (ex. where is this? or what happened before the flood?) If they haven't, give them a moment to write down any wonderings that they have. Tell students that they are now going to generate some questions from their wonderings to use during their investigation. Pass out a few sticky notes to each student, and tell them to write one question that they have per sticky note. The questions should be things they want to know about what they see in the pictures. They can come directly from their wonderings or they can be totally different questions. For example: Where did the water come from? Did the water stay like that or did it go back down? What time of year did the flooding happen? Was it raining a lot before the flooding happened? How often does this flooding happen? What caused this flood?

   If students struggle to come up with questions, have them think about what they see to help them make up questions.

4. **Organizing questions**. Have students start by sharing their questions with one another in a small group. If two people have the same (or very similar) questions, they should put the sticky notes together. Next, have each group share one of their questions with the whole group, and put that question up on the wall or a piece of chart paper. Rotate from group to group, sharing questions. If one group has a similar question, put the sticky notes together. Once all the questions are up, have students organize the questions around particular topics. For example: questions that have to do with weather (did it rain before the picture?), location (where are these pictures from?), time (what time of year was this?).

5. **Create big guiding questions:** Using the groups of questions, see if students can come up with one question that summarizes all of the questions in the group. Ex: Does this kind of flooding happen in particular places? or What is the weather like when this flooding happens? Do this together as a whole group to support students in generating good questions.

6. **How to investigate?:** Ask students how scientists answer questions. Write their responses on the board: ex. they ask other scientists, they look things up, they conduct experiments.

TEACHER NOTES

Modification

- ✓ If students have a lot of questions, consider having them choose the top 3 questions from their group to share out loud, and put the rest up on the board at the end.
- ✓ To help organizing the questions, you may want to write them in large print on pieces of paper so students can see more easily.

TEACHER NOTES

Teacher Tip

- ✓ Some of the questions that students come up with will be ones that you will answer during the module, and others will go beyond what you have planned. The same is true of their ideas for investigation. Consider ways you can either modify upcoming activities to address their questions, or ways that you can incorporate some of their ideas for investigation into your plan. Ultimately, you will not be able to answer all students' questions through the module activities, or follow all of their suggestions. Think about other ways to make sure students recognize their ideas are valid: ex. a suggested experiment might be good for science fair or an extra credit project. Unanswered questions may be divided up and answered as a homework assignment.

Recommended

- ✓ Have students read the interview with the module's Air Quality Champion to get them into the frame of mind of what they'll be investigating

Next, ask students how they can investigate their own questions. Can they look up the answers? Do they need to perform an experiment?

Assign one big guiding question to each group of students and have them create a list of ways they could find out the answers to their big question. Make sure they are specific (ex: "Look up places that have sunny day flooding" vs. "look it up") If they get stuck, have them use the little questions to help them figure out how they might answer the big question.

7. **Share out:** Have each group share out their suggestions for how to investigate the answers to their questions. Record these on chart paper to put up with the questions. When each group is done sharing, allow other students to ask them questions, or add additional ideas.

8. **Next steps:** Tell students that they have made a great start in figuring out this strange phenomenon of the sunny day flood. During the course of the investigation, they'll do some of the suggested investigations in order to answer their questions, and maybe even figure out some ways to address it. Put the questions and the suggested investigations up on the wall for future reference.

9. **Formative assessment**: Have students answer the prompt: What question is the most interesting one that you want to answer? Why?

Air Quality Champion

Vernon Morris is both an atmospheric researcher with NOAA, and a Howard University professor. Learn more about Vernon's work and his journey to where he is now at the end of the module.

Name ______________________________

STUDENT HANDOUT

Phenomenon: I See I Wonder

I see	I wonder

Activity 2 (Explore): Where Does Sunny Day Flooding Happen?

ACTIVITY DETAILS

Time: 45-60 minutes

Objectives

- ✓ Students will use maps to determine the location of sunny day floods in order to investigate the cause of the phenomenon.
- ✓ Students will understand how sea level rise affects coastal communities

Materials

- ✓ Computer & projector
- ✓ Student computers (highly recommended)

Handouts

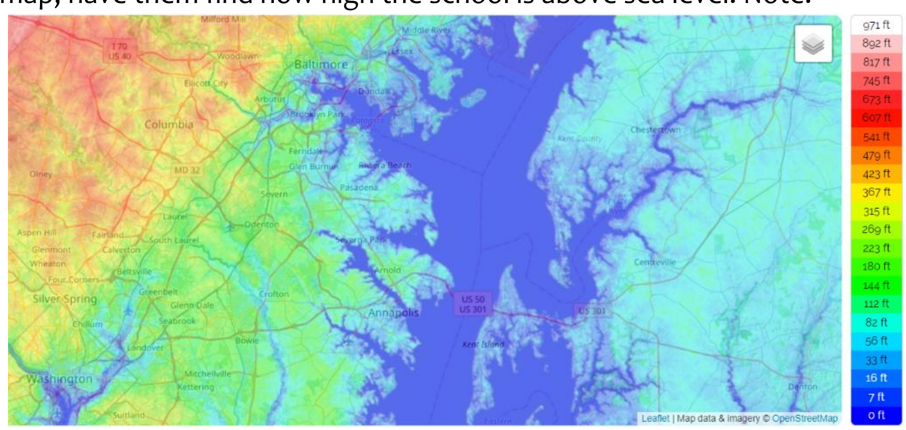
- ✓ Sunny Day Floods

Activity summary: In this activity, students investigate the phenomenon of sunny day floods by looking at elevation and flooding maps, and then by using NOAA's online Sea Level Rise viewer. Through their research, students learn where sunny day flooding occurs, and how different sea level rise scenarios affect different communities, including their own.

<u>Standards Connection</u>

DCI: ESS 3.C: Human Impacts on Earth Systems
SEP: Analyzing data
CCC: Cause & Effect, Patterns

Warmup: Show students the map below, and tell them that this map shows the elevation (height) of land above sea level. The height is shown on the scale on the right. Have them use the scale to see about how high Annapolis, MD is above sea level (they can provide a range). If they are on the map, have them find how high the school is above sea level. Note:

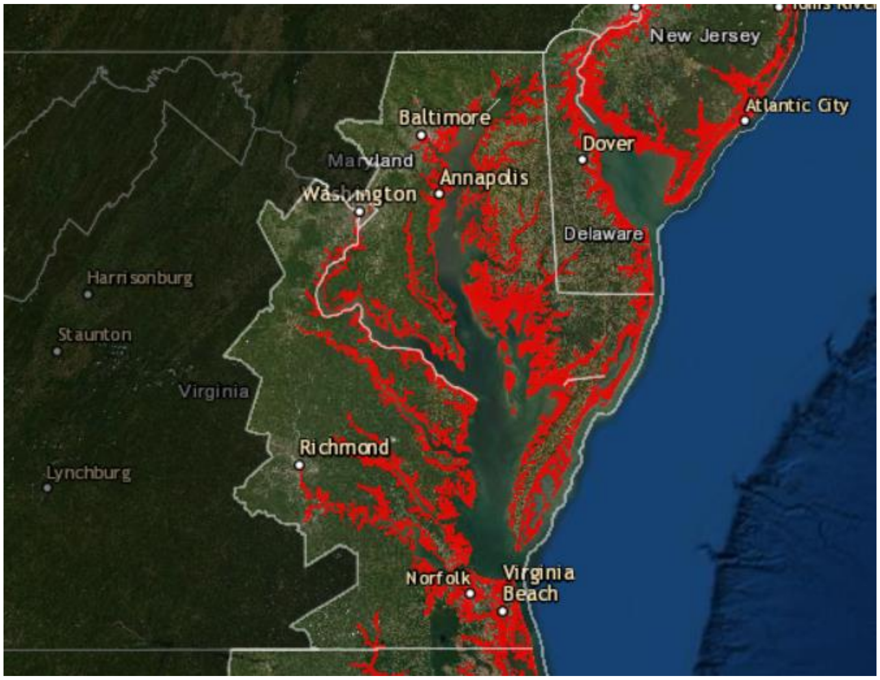


You can also go to this map at https://en-au.topographic-map.com/maps/kh4d/Severn-River/ and move it around, zoom in, or click to see the elevation in a particular location. Use the dropdown menu at the top to select English (United States) for measurements in feet.

> **Answer:** Annapolis ranges from about 1' to 64' above sea level in different places.

1. **Frame the activity:** Look at the big guiding questions that students came up with in Activity 1. Find a question that relates to the location of the flooding, as well as an idea for investigation (if there is one). Tell students that today they are going to investigate where sunny day flooding occurs to help answer their question. If possible, make a connection to their idea for investigation as well.

2. **Where does sunny day flooding happen?** Show students the map below which shows areas of the region (in red) that currently experience sunny day flooding.



Ask students what they notice about what areas are red (they are all along the coast or along rivers). Ask students what would cause the areas along the coast to flood more often. Have them turn to a partner to discuss, and then hear answers. Use questions if necessary to help students come to the conclusion that if the sea level of the ocean is rising, then areas that are along the ocean or near it will experience more flooding.

3. **Annapolis under water:** Ask students where they think the pictures came from that they saw during Activity 1. They will likely say that they came from somewhere in the red area. Two of the pictures came from Annapolis, MD:

And one from Cambridge, MD on the Eastern Shore:

TEACHER NOTES

Map sources

- ✓ The maps for this part of the activity come from the National Oceanic and Atmospheric Administration (NOAA). Go to coast.noaa.gov/slr to access them.

Tech Tip

- ✓ If student computers are not available for the Sea Level Rise Viewer part of the activity, then it is best for the class to do the activity together using a computer connected to a projector, so they can all see as the maps change.

TEACHER NOTES

Why Annapolis?

- ✓ The student handout is based around Annapolis, MD because it experiences sunny day floods on an increasingly regular basis. You can also have students look at other cities nearby. There are high tide flood scenarios and local scenarios for Washington DC, Baltimore, Richmond (local scenario only), and other cities nearby.

Additional media

- ✓ The National Environmental Modeling and Analysis Center has graphs and other data including predicted number of flood days in the DC/ Baltimore Region. Use the link below and click on one of the blue dots on the map to access their flood days graphs for that location: https://tinyurl.com/flooddays

Tell students that they are going to look more closely at what happens when the sea level rises in places like Annapolis and Cambridge using a computer simulation.

4. **Sea level rise viewer:** Pass out the Sunny Day Floods sheet to students. If they are using student computers for the activity, pass out the computers now and have students go to http://coast.noaa.gov/slr. If student computers are not available, it is best to lead them through the activity together as a whole group using a computer connected to a projector.

   Even if students are using computers, you should walk them through the first few steps of the directions to make sure they are able to use the NOAA Sea Level Rise Viewer.

   While students are working on the activity, circulate and support as necessary. Sometimes finding the right button to click on the map may be difficult. Zooming out can often help with this, although sometimes you may need to refresh the page and go back to the location.

   When students are done with the viewer (up to the summary portion), collect student computers and lead the discussion below before having students complete the summary.

5. Discussion: Ask students what they learned from using the sea level rise viewer. Use questions to help drive the conversation if these key points don't come up naturally:
   - Sea level rise affects low elevation coastal communities and those near rivers the most
   - Sunny day floods are caused by sea level rise
   - The number of sunny day floods will continue to rise if the sea level continues to rise
   - Vulnerable communities may end up completely underwater
   - People who live in vulnerable communities will have difficulty going about their lives and work if sea level continues to rise. They may have to move somewhere else.

   Close the discussion by asking students if they know what is causing the sea level to rise (don't give them any answers, this is a teaser for the next activity).

6. **Formative assessment**: Have students complete the summary section of their Sunny Day Floods sheet.

Name ____

STUDENT HANDOUT

Sunny Day Floods

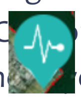
1. Using your computer, go to http://coast.noaa.gov/slr. This is the National Oceanic and Atmospheric Administration (NOAA) website for sea level rise. Click "Get started" to begin.

2. At the top of the page, where it says, "Enter an address or city" type in Annapolis, MD and click on it when it pops up.

   Look at where Annapolis is. What is the area around Annapolis like? ______________________

   ____

High Tide Flooding

3. On the left side of the map, click "High Tide Flooding." A little heartbeat icon will pop up next to Annapolis that looks like this:  Click on the icon to learn more about how much flooding happens in Annapolis. If you move your cursor over the graph, you can get information for specific years.

4. What year had the most flood days in Annapolis? ______________ How many? ____________

5. What is the greatest number of flood days in Annapolis in one year before 1983? _______

6. Look at the years 2010-2017. What is the range of the number of flood days per year (the range is the lowest amount to the highest amount) (lowest) ___________ - ______ (highest)

7. What is the mean (average) number of flood days per year from 2010-2017? To find the mean, add up the total number of flood days from 2010-2017 and divide by the number of years. The average number of flood days from 2010-2017 is: ______________________________

8. Do you think flooding in Annapolis is getting worse or not? Explain your answer using information from the graph. ____

   ____

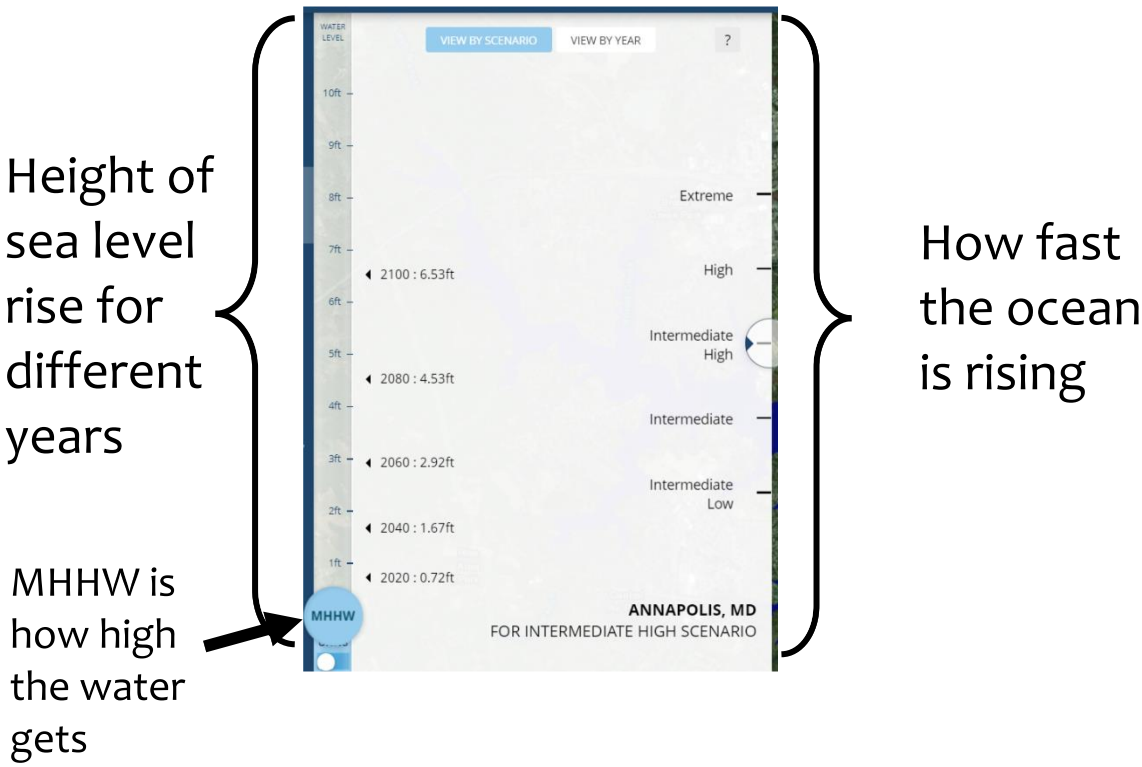
   ____

   ____

Local Scenario

9. On the left side of the map, click "Local Scenarios." A little house icon will pop up next to Annapolis that looks like this:  Click on the icon to start the local scenario.

10. A box like the one below will pop up on the left. You can move the sliders on either side of the box to change how high and how fast the ocean is rising. Zoom in using the + button in the bottom right to see Annapolis up close. Then try moving the sliders and seeing how the map of Annapolis changes.



11. What happens to Annapolis if you raise the sea level up to 10 feet? (what do you think the light blue means?) ____

____

12. Move the slider on the right to "Intermediate High." This means that the ocean is rising a medium amount. Now look at the left side of the box. In what year will the ocean be 2.92 feet higher? ____________________

Move the left slide to 3 feet. How bad is the flooding in Annapolis in this scenario? __________

____

13. Now move the slider on the right to "Extreme." This means the ocean is rising a lot. Now how high will the water be in 2060? ____________________

Move the slider on the left to 5 feet. How bad is the flooding in Annapolis in this extreme scenario in 2060? ____________________

____

Vulnerable Places

Vulnerable places are those places that are in the most danger from sea level rise. Choose one or more of the vulnerable places below to investigate and circle the location on your paper. Use the search bar above the map to find the location.

Tangier, VA   Ocean City, MD   Toddville, MD Lewes, DE

14. When you are centered on the location, click on the "Sea Level Rise" button on the left and set the water level to "Current MHHW."

Where is your location (ex: Is it an island? Is it at the beach? Is it on the coast?)____________________

____

15. What does your location look like (is it flooded or dry land)? ____________________

____

Move the slider up to raise the sea level. How far do you have to go before the area is mostly underwater? ____________________

16. Find the nearest picture by clicking on a water drop that looks like this:  You may need to zoom out to find it. When you click on it, set the water level to MHHW. What do you see? ________

____

Try moving the slider up to 3 feet, 7 feet, and 10 feet. What does the location look like now? What would it be like if you were there?____________________

____

____

17. Do you think the people in your vulnerable area should be worried about sea level rise? Why or why not? ______________________________

____

____

My Home

18. Put your town into the bar above the map and use the tools you have learned about today to see if your community will be directly affected.

    Will your community be flooded by sea level rise? ______________________________

    Why might you care about sea level rise even if your community is not directly flooded? ________

    ____

    ____

    ____

    ____

Summary

1. What is causing the sunny day floods? ______________________________
2. What areas are most affected by sea level rise? ______________________________

   ____

3. What do you expect will happen to the number of sunny day floods if sea levels continue to rise?

   ____

   ____

4. Imagine you are a business owner on a street near the harbor in Annapolis. How do you think your business will be affected by sunny day floods? ______________________________

   ____

   ____

   ____

   ____

Activity 3 (Explore): Why Are Sea Levels Rising?

Activity summary: In this activity, students design and run experiments to determine whether sea ice or land ice is having a bigger effect on sea level rise. They then use this information to draw conclusions about which is more responsible for the sunny day flooding from their original phenomenon.

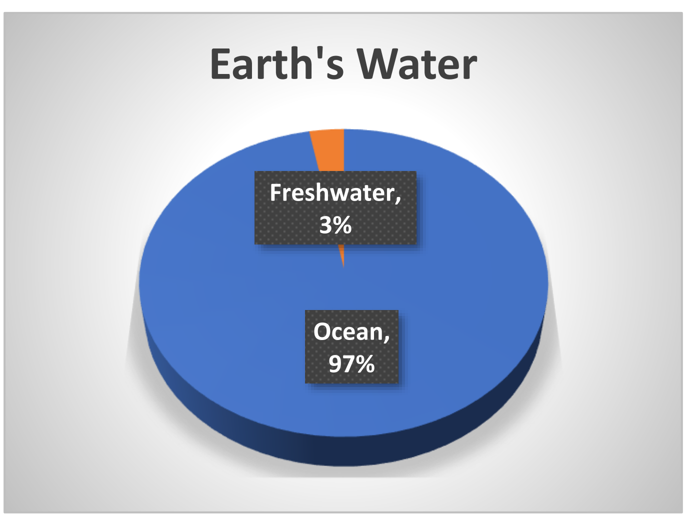
Standards Connection
DCI: ESS 3.C: Human Impacts on Earth Systems
SEP: Planning & Carrying Out Investigations
CCC: Cause & Effect

Warmup: Name as many places as you can think of where there is water (in any form) on Earth.

- Possible answers: lakes, rivers, the ocean, the atmosphere, ice, snow, the ground, etc.
- Have students share when they are done with their lists, but don't discuss further (they will use these lists shortly)

1. **Frame the Activity:** During our last activity, we learned that sea level rise is causing the sunny day flooding. The next question we have to answer then, is what is causing the sea level rise? During today's activity, we're going to do an experiment to help figure out why the ocean is rising. If students asked any questions in Activity 1 related to sea level rise (or where the water is coming from), tell students they they'll be investigating this question today.

2. **Where is the water coming from?** Have students consider the lists they made during their warmup, and ask what percentage of the world's water is in the ocean. They will likely know that most of the water is in the ocean, but they may be surprised how high the percentage is (97%). Show them the pie chart below:



ACTIVITY DETAILS

Time: 1-2 class periods

Objective
- ✓ Students will design and conduct experiments to determine the effect of melting land and sea ice on sea level change.

Materials
(see activity for details on these materials)
- ✓ Ice, Water, Measuring cups, Containers, Rulers, Clay or other materials to make "land"
- ✓ Scale (optional to weigh ice)
- ✓ Heat lamp (optional)
- ✓ Computer & projector

Handouts
- ✓ What is Causing the Ocean to Rise?

Source
- ✓ This activity is based on NASA's *What's Causing Sea-Level Rise? Land Ice vs. Sea Ice*: https://www.jpl.nasa.gov/edu/teach/activity/whats-causing-sea-level-rise-land-ice-vs-sea-ice/
For additional photos and tips on the experiment, check out their website.

TEACHER NOTES

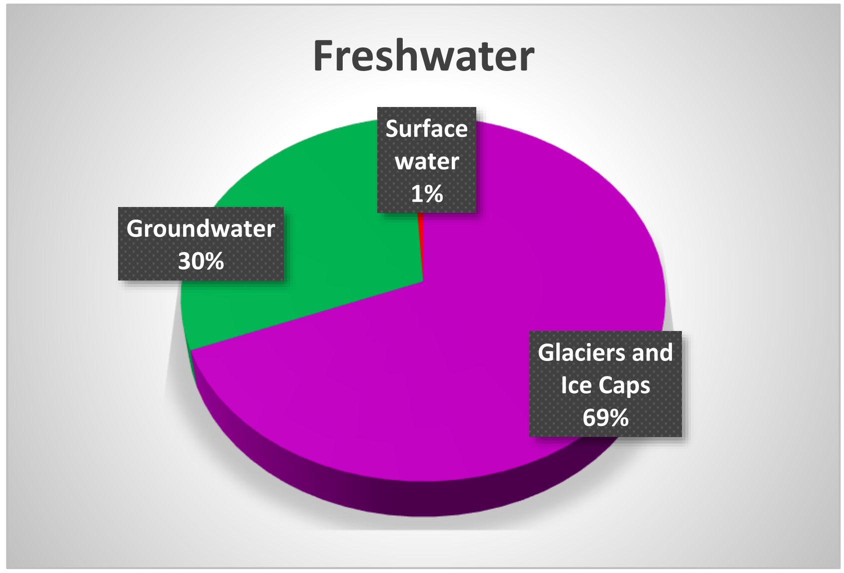
Materials

- ✓ This activity can be done in small groups (recommended) or as a whole group. If it is done as a whole group, use a larger container to make it easier for all students to see.

Melting ice vs. thermal expansion

- ✓ In this activity, students learn about how melting land ice affect sea level rise. Thermal expansion (when water expands as it is heated) also plays a major role in causing sea level rise. How much each of these factors affects sea level rise is still debated today. While there is not space in this activity to introduce students to thermal expansion in detail, it is worth bringing it up when time permits. See the article below for more information on the debate: https://www.carbonbrief.org/extra-water-or-more-heat-whats-driving-sea-level-rise

Next ask them where the 3% is. They will likely say things like the lakes, rivers, the air, etc. If they don't mention it, ask about water in another form. See if students recognize that some water is frozen. What percentage of the 3% is frozen as ice? Show students the pie chart below, which breaks up the 3%



Students may be surprised to find that more than 2/3 of the freshwater on the planet (2% of the total) is frozen as ice in glaciers and ice caps (make sure students know what a glacier is). 1% of the total is in the ground, and only a tiny fraction (about 0.007%) is in lakes, rivers, and swamps.

Ask students: if the sea level is rising, where do they think the water is coming from? They will likely say it is coming from the melting ice. Tell them that during their experiment today, they are going to investigate how melting ice can affect sea levels.

3. **Land ice vs. sea ice:** Hand out the "What is Causing the Ocean to Rise?" sheet to students. Show students these two pictures and ask them what the difference is in what they see (the pictures are also on their sheets)

There are several differences, but the important one to help students see is that in the picture on the left, the ice is on land, and the picture on the right, the ice is floating in the ocean. Once picture (on the left) is Antarctica, and the other is the Arctic Ocean. Have students label the left picture "land ice" and the right picture "sea ice." Ask them where land ice is found (mountains and Antarctica) and sea ice (the Arctic Ocean). Ask students if they think land ice melting or sea ice melting is doing more to cause sea level rise. Have them write this research question on their sheets.

4. **Design the experiment:** This experiment requires a very simple setup, so rather than tell students what to do, have them design their own experiments given the materials you have. In general, student groups will need:
   - ❒ 2 identical containers (one each for sea and land ice) approximately 6" x 6"
   - ❒ Ice
   - ❒ Water
   - ❒ Something to make land out of (blocks of wood, clay, a jar, etc.
   - ❒ Something to measure height (ex. a ruler)

   Tell students what materials you have available (having additional materials will give them more flexibility in their designs).

   Form students into groups and have them brainstorm ways they could test whether sea ice or land ice will make the ocean level rise higher. When they have an idea, they should share it with you for approval. You may also choose to have students share ideas as a whole group. If students are stuck, consider asking questions such as:
   - What will you need in order to *compare* sea ice vs. land ice?
   - How can you simulate land ice?
   - How can you simulate the ocean?
   - How will you measure sea level rise?

   Have students write down the materials they will use for their experiments, and draw their designs in the boxes at the bottom of their data sheets.

TEACHER NOTES

Differentiation
- ✓ Depending on students' level of experience designing their own experiments, they may have an easier or harder time getting started. You may want to brainstorm together as a class before having student groups work on their own.

Teacher Tip
- ✓ The amount of ice in each container need to be the same. If you don't have ice cubes that you can count, suggest to students that they use a scale to weight out equal amounts of ice.

Timing Tip
- ✓ It is possible to do this experiment in a shorter time period if you set up a heat lamp or put experiments in a sunny location where the ice will melt more quickly. This will also prevent evaporation from being a variable.
- ✓
- ✓

TEACHER NOTES

Teacher Tip

- ✓ If you are short on materials, pair up groups that have similar designs so that one builds the sea ice setup and one builds the land ice. Just make sure they work together to ensure the amount of ice and water is the same.

5. **Variables, controls, and data gathering:** On the back of their sheets, have students consider what they are changing between the two setups (independent variable), what they are measuring (dependent variable) and what needs to be the same for both of their setups (controls). In general, these will be the same for all groups:
   - Independent variable: ice on land vs. ice in water
   - Dependent variable: the height of the water
   - Controls: same container, same amount of ice, same amount of water

   Also have students describe how they will measure the water rise, and what units they will use.

6. **Write a hypothesis:** Have students write a hypothesis about whether they think the land ice or the sea ice will make the water rise more. Encourage them to think about why the land or sea ice will make the water rise more.

7. **Build the setups:** When you are confident that students understand what they are doing, have them build their setups. As they are building, make sure they are measuring the amounts of ice and water they put into each container to be sure they are equal. Also check that the ice in the "sea ice" container is floating (not sitting on the bottom), and the land ice is above the water level.

   As groups finish building, make sure they measure the height of the water as quickly as possible before the ice starts melting.

8. **Run the experiment:** If you are having students leave the experiment overnight, then make sure you have at least 1-2 measurements before they leave class. If you are using a heat lamp, you may want students to take measurements at regular intervals. The data sheet on their handout is flexible to accommodate various methods.

9. **Data analysis:** When students have collected all their data, have them analyze the data by determining which water level rose more and by how much. You may choose to have students graph their data (especially if they took data at multiple points), but since the most consequential data is the beginning and ending points, it is not necessary.

10. **Sensemaking discussion:** As a whole group, have student groups share their results. Did everyone get the same result? Why or why not? Use discussion techniques to have students consider why the water level rose more in the "land ice" than the "sea ice." While they do not need to understand the physics of buoyancy, they should understand that the ice on land was added to the water level, making it go up. The ice in the water was already there, so when it melted, it didn't make the water go up at all.

11. **Check in with questions:** Go back to students' question board from Activity 1. Are they able to answer any of the questions they asked? If so, take a moment to acknowledge this and make note of what they've figured out.

12. **Conclusions (formative assessment):** Have students complete the conclusions section of their experiment handout, including why the water rose more in one container than the other, and which kind of ice melting they think is causing the sunny day flooding from their original phenomenon.

TEACHER NOTES

Experiment Reflection

- ✓ If you have time, have students reflect on their experience of designing and running their own experiments. What did they like? What was frustrating? What would they do differently next time? This opportunity to reflect on the process of science is useful in helping students learn to think like scientists.

Group Names____________________________________

STUDENT EXPERIMENT

What is Causing the Ocean to Rise?

Type of ice: ______________________________

Found in: ________________________________

Type of Ice: ______________________________

Found in: ________________________________

Research question: ____

____

Materials

-
-
-
-
-
-

Experimental Design

In the space, draw a picture of what your land ice setup will look like, and what your sea ice setup will look like:

Land ice	Sea ice

Variables & Controls

What is your independent variable? (What are you changing between your two setups?) ____________

____

What is your dependent variable (What are you measuring?) ____________

What are you controlling (What needs to be the same in both of your setups?) ____________

____

Data

How will you measure your sea level rise? ____________

____

What units will you use? ____________

Hypothesis

Do you think the land ice or sea ice will make the water rise higher? (you can also say they will rise the same amount)

____

____

Use the table below to record your data:

	Land Ice	Sea Ice

Analysis

What does your data show? (how much did each water level change? which rose more? By how much?) ____________

____

____

____

Conclusion

Was your hypothesis correct? ______________________________

Why did the water rise more in one container than the other? ______________________________

What kind of ice melting is causing sunny day flooding? Explain how you know using the result of your experiment:

Activity 4 (Explain): Rising Temperatures, Rising Tides

Activity summary: In this activity, students look at a series of graphs showing global temperature and carbon dioxide levels to make the connection that the two are correlated. Then they watch a video about the greenhouse effect to see how carbon dioxide is causing global temperature increases. Finally, students fill in a cause & effect graphic organizer that traces each step from greenhouse gases to the sunny day floods in their phenomenon.

Standards Connection
DCI: ESS 3.D: Global Climate Change
SEP: Analyzing Data; Constructing Explanations
CCC: Cause & Effect; Patterns

Warmup: Show students this video from NASA showing how global temperatures have risen from 1880-2018: https://www.youtube.com/watch?v=gXXOkhoki8s. Try to keep the title of the video off the screen, and at the end, have students guess what they think the video is showing. Don't tell students whether they are wrong or right: you will come back to this video later, so use this video as an opportunity to spark students' curiosity about what they will be learning today.

1. **Frame the activity:** Remind students that in their last activity, they learned that one of the causes of sea level rise is melting land ice (Antarctic ice and glaciers, largely in Greenland). But why is the ice melting in the first place? In today's activity, they are going to study why the ice is melting. If any students posted a question about climate change or global warming in Activity 1, tell them they will investigate the answers to those questions today.

2. **Global temperature change:** Ask students what could cause the ice in Antarctica to melt. Students should say something about the temperature (ex. that it is too hot). Tell them that the first piece of evidence they should look at then is the temperature. Since ice is melting all over the planet, they will look at a graph of global temperature first.

   Hand out the Rising Temperatures, Rising Tides sheet to students and have them look at the graph on the first page. You can also display the graph on the projector so they can see it in color.

ACTIVITY DETAILS

Time: 60 minutes

Objectives

- ✓ Students will analyze graphs to identify the correlation between carbon dioxide concentrations in the atmosphere and global temperature increases
- ✓ Students will be able to explain the greenhouse effect in order to show how carbon dioxide is causing global temperature increases

Materials

- ✓ Computer & projector
- ✓ Speakers for video

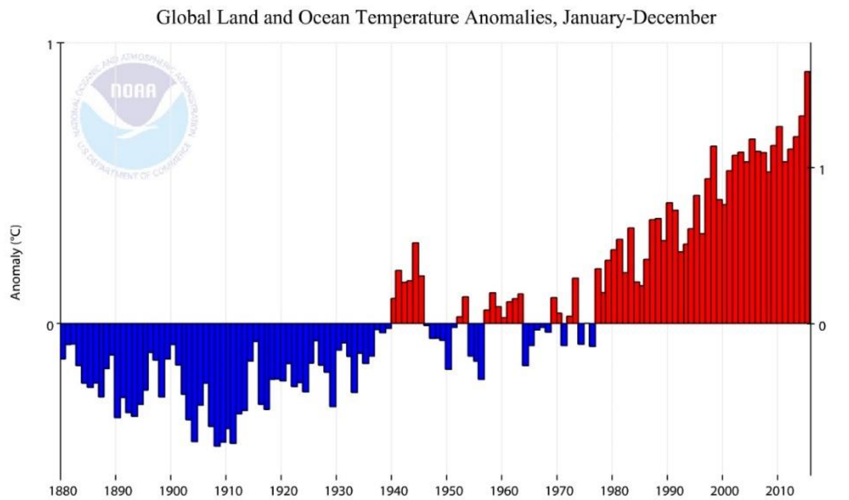
Handouts

- ✓ Rising Temperatures, Rising Tides

TEACHER NOTES

Source Data

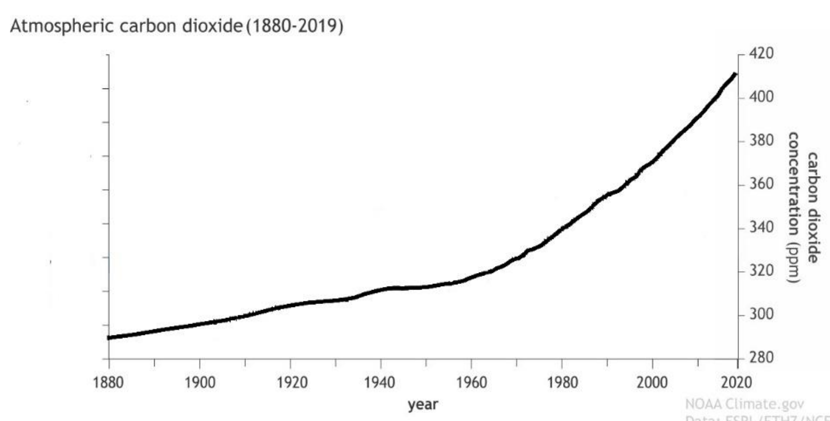
- ✓ Most of the graphs in this activity come from the National Oceanic and Atmospheric Administration (NOAA). See individual graphs for specific sources.



Take a moment to help students understand what the graph is showing, then have them answer the questions below the graph.

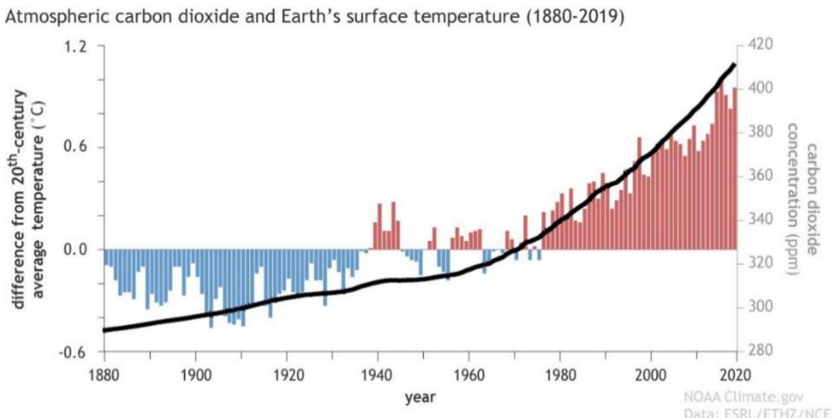
Review just the final question with students to make sure they understand that global temperatures are rising. Then go back to the NASA visualization video and make sure students see the title and the scale in the top left. Show the video again so students see the two different ways to display similar data.

3. **Carbon dioxide levels:** Have students look at the next graph and project it:



Have students answer the questions below the graph. Students will study the idea of parts per million in a later activity, but it is a good idea to mention to them that parts per million is a measurement that is similar to percent (parts per hundred). One part per million is that same as 0.0001%.

4. **Global temperatures & carbon dioxide levels:** Have students look at the third graph and project it:



Have them answer the question below it. You can review quickly afterwards, but students should have a good sense at this point that carbon dioxide levels and global temperature are correlated.

5. **Reading: correlation vs. causation:** Have students read the short passage on correlation vs. causation. This topic is always tricky for students to grasp, so take the time to review it with students afterwards. The key point in this reading for students to take away is that the data looks like carbon dioxide might be causing the global temperature to go up, but as scientists we need an explanation of why.

6. **The Greenhouse effect video:** Show this video on the greenhouse effect from the US EPA: https://www.youtube.com/watch?v=VYMjSule0Bw. Afterwards, have students turn to the next page in their handout so they can fill in the graphic. You can show the video a second time (it is short) to help students with the graphic. When they are done, discuss what they learned about the greenhouse effect. Key takeaways:
   - The greenhouse effect is necessary to keep Earth warm enough for us to live
   - The greenhouse effect works by trapping heat in Earth's atmosphere
   - Carbon dioxide is a greenhouse gas
   - Humans produce extra carbon dioxide by driving cars and using energy
   - Too many greenhouse gases are causing the Earth's temperature to rise

TEACHER NOTES

Human Population and Carbon Dioxide Emissions

- ✓ Rising carbon dioxide concentrations are due to increasing amounts of carbon dioxide emissions. Why emissions are rising is a more complicated story. In many places (including the US) *per capita* emissions are going down, but the *population* is going up, thus leading to higher emissions. If you have time, consider showing students this graph: https://tinyurl.com/populationCO2emissions as a way to talk about correlation, causation, and why CO_2 levels are rising.

Alternative Media

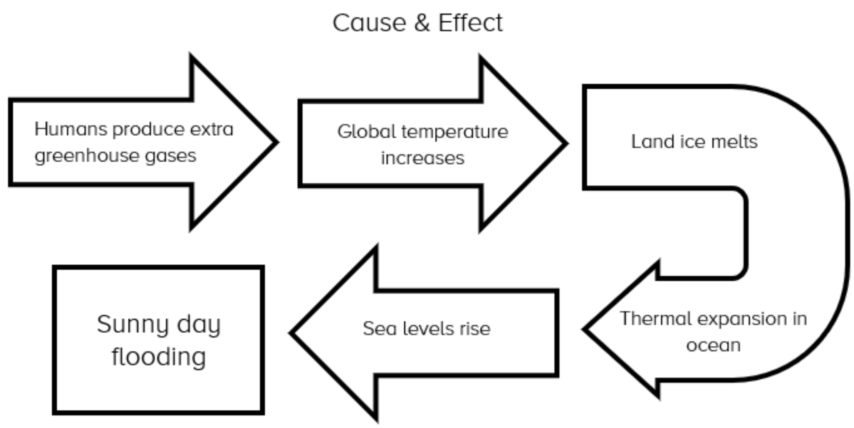
- ✓ There are many good videos available that explain the greenhouse effect. The one listed here is accurate and straightforward, but if you are interested in providing further detail, you may want to show one or more additional videos.

TEACHER NOTES

Modification

✓ Since this formative assessment is rather complex, you may choose to use the cause and effect organizer as your formative assessment and save this writing piece for later in the module.

7. **Cause & effect:** Now that the class has made connections among sunny day flooding, rising ocean levels, melting ice, rising global temperatures, rising carbon dioxide levels, and the greenhouse effect, see if students can fill in the cause and effect organizer. Make sure students understand that the arrows mean one thing *causes* the following effect, which then causes the next effect. There are a variety of ways that students can fill it in; the key is to help students internalize the cause effect relationship from one step to another. A sample cause-effect organizer is below:



Make sure to return to the causation/correlation discussion to ask students if they think carbon dioxide concentrations and global temperature are only correlated, or if one is actually causing the other.

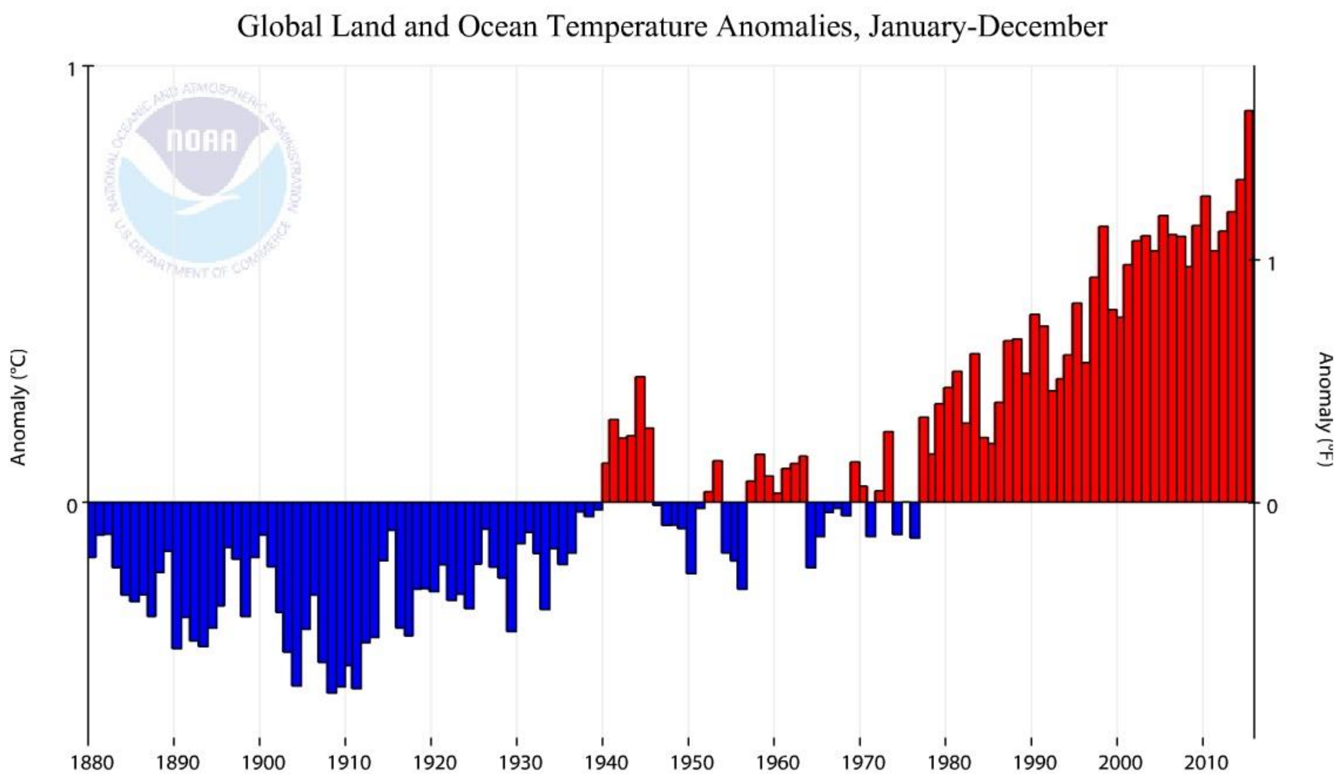
This cause and effect organizer helps to answer a lot of questions that students may have had during Activity 1, so go back to the questions board to see if there are any big questions you can answer now. If so, you may want to have students answer the question in place of the formative assessment below.

8. **Formative assessment:** Using your cause and effect organizer, and what you've learned so far in this investigation, explain how extra greenhouse gases like carbon dioxide are causing the sunny day flooding in Annapolis.

Name ____________________

STUDENT HANDOUT

Rising Temperatures, Rising Tides



This graph shows whether the temperature in each year is hotter than average or colder than average. If a year is at 0, then it means the temperature is exactly at the average.

1. Look at 1880-1940. Is the temperature above or below average for these years? ____________________

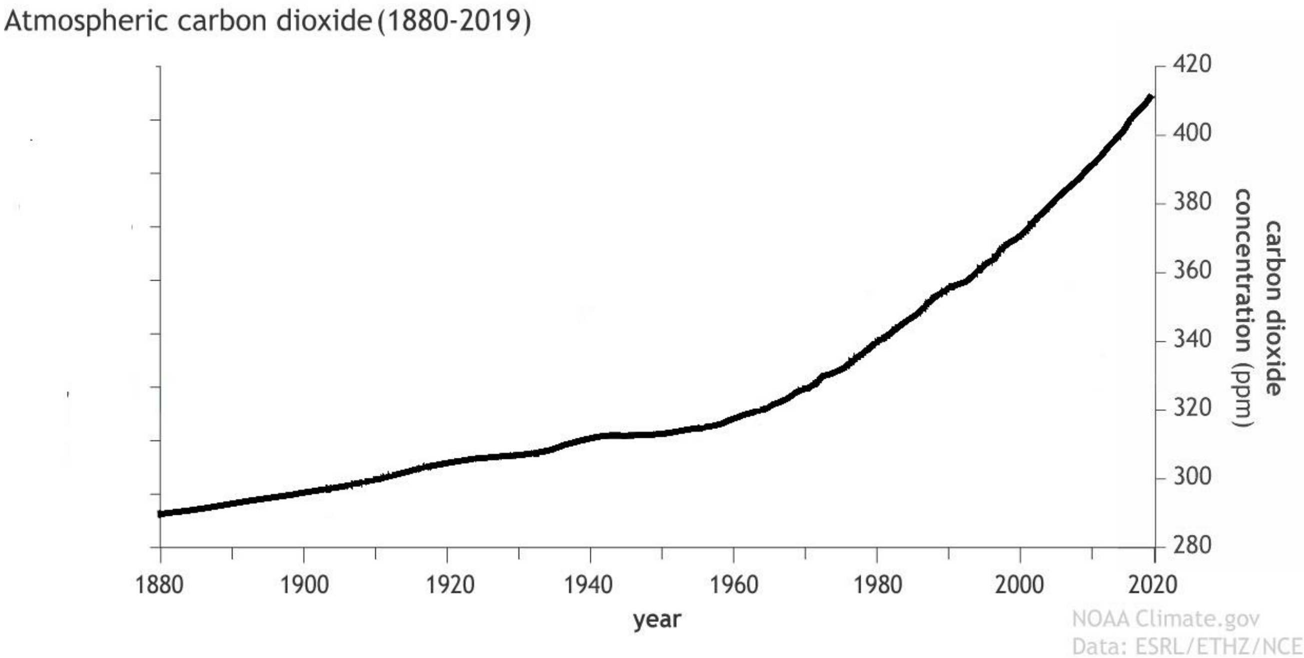
____

2. Look at 1980-2015. Is the temperature above or below average for these years? ____________________

____

3. What is the hottest year you can see? ____________________
4. How far above average is that year? ____________________
5. Based on this information, what would you say is happening to the global temperature? ____________________

____

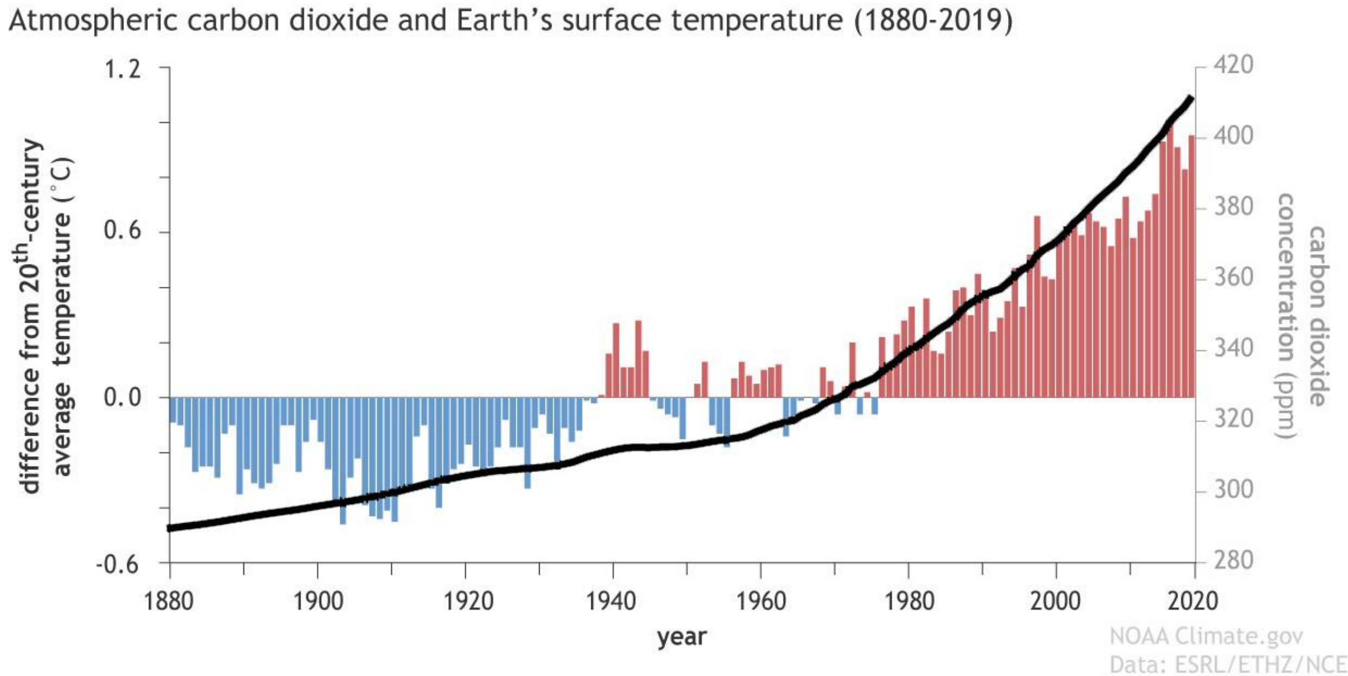


This graph shows the concentration of carbon dioxide in the atmosphere during the same time period.

1. How does the concentration of carbon dioxide in the atmosphere change? ________________

____

2. Carbon dioxide concentration is measured in parts per million. What is the lowest concentration in the graph? ______________ What is the highest? ______________
3. Using your answers from the last question, how much has the concentration of carbon dioxide gone up from 1880-2020? ____



This graph shows the concentration of carbon dioxide in the atmosphere and the temperature at the same time.

1. What pattern do you notice in the amount of carbon dioxide in the atmosphere compared to the temperature change? ____

____

Reading: Correlation vs. Causation

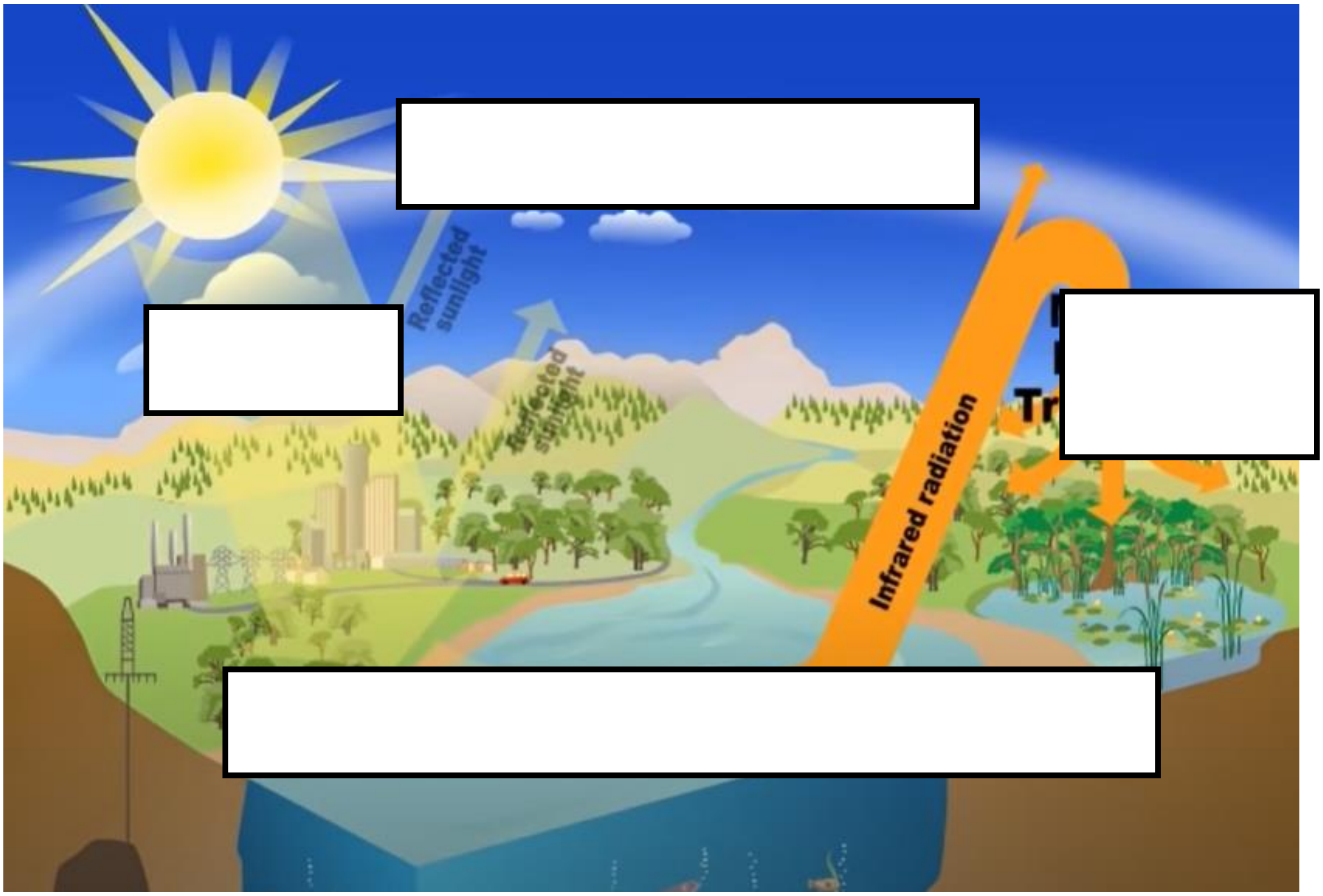
Scientists noticed that the concentration of carbon dioxide in the atmosphere and the global temperature seem to go together. As one went up, the other went up. When two things seem to go together like this, scientists say that they are correlated. The prefix "co-" means together as in cooperate and copilot. When things are correlated they are related together. If scientists see that things are correlated, they often try to figure out if one thing is causing the other thing.

Just because two things are correlated doesn't mean one thing is causing the other. For example, students who are in higher grades are also taller. Does that mean that being in a higher grade **causes** you to be taller? Of course not. There is another factor – your age – that is related to being taller and being in a higher grade.

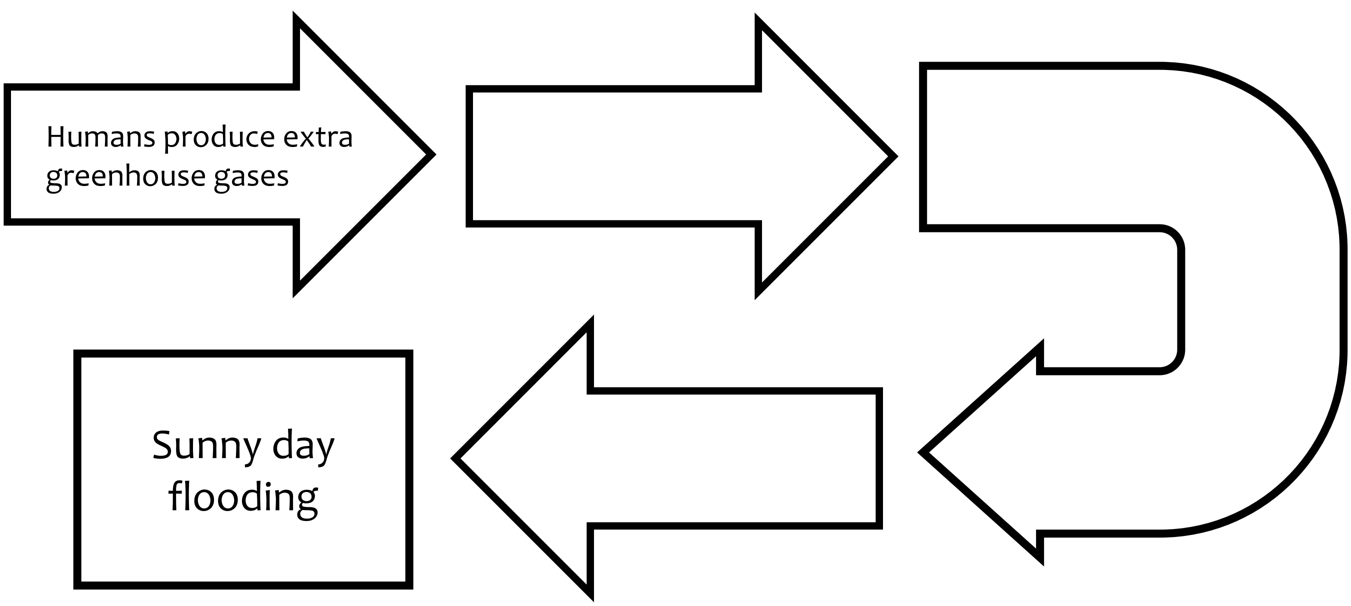
Can higher carbon dioxide concentrations **cause** temperatures to rise? That's a great question to ask. We will learn about that now!

Video: The Greenhouse Effect

Watch the greenhouse effect video and fill in the spaces with the correct information.



Cause & Effect



Activity 5 (Explore/Explain): The Greenhouse Effect & Urban Heat Islands (optional)

Activity summary: In this activity, students perform a series of experiments that show how the greenhouse effect causes higher temperatures by trapping heat. They also demonstrate how different surfaces affect how much heat is absorbed by the Earth, which contributes to the urban heat island effect.

Standards Connection
DCI: ESS 3.D: Global Climate Change
SEP: Planning & Carrying Out Investigations
CCC: Cause & Effect

Warmup: Have you ever walked barefoot on hot pavement during the summer? What was it like? What other surfaces get very hot in the summer? What surfaces stay cooler?

- Hot surfaces: sand, rocks
- Cool surfaces: grass, dirt

1. **Frame the activity:** Ask students if they think the surfaces they talked about in their warmup have any effect on the temperature of the atmosphere. Tell them that today they're going to design experiments to test their answers.

2. **The urban heat island effect:** Go to the climate.gov website for the DC/Baltimore heat island effect (https://www.climate.gov/news-features/features/detailed-maps-urban-heat-island-effects-washington-dc-and-baltimore) and show students one of the maps (see example on the next page). You may want to zoom out so students can see the whole map. Make sure they understand the temperature scale at the bottom, and move the slider back and forth. Ask students what they notice about where the temperature seems to be hotter or cooler. It should be relatively easy for students to recognize that the temperature is hotter where there is pavement, and cooler where there is grass and trees.

   Tell students that scientists call this the "Urban heat island" effect. It is called a heat island because the high temperature air is like an island surrounded by cooler air. They are urban because they are mostly found in cities. Ask students why they think they are mostly found in cities (because cities have a lot of pavement).

   Ask students why they think urban heat islands can be harmful (temperatures can get well over 100° in the summer).

ACTIVITY DETAILS

Time: 1-2 class periods

Objectives
- ✓ Students will perform experiments to simulate how the greenhouse effect works
- ✓ Students will perform experiments to explain one cause of the urban heat island effect

Materials
- ✓ Computer & projector
- ✓ Glass jars with a whole punched in the lid for a thermometer
- ✓ Thermometers
- ✓ Black and white construction paper
- ✓ Other "surface" materials: soil, grass, rocks, sticks, sand, roof shingle, water, etc.
- ✓ Stopwatch (at least one)
- ✓ Clipboards (optional, for recording data outside)
- ✓ Graph paper (optional)

Handouts
- ✓ The Greenhouse Effect and Urban Heat Islands

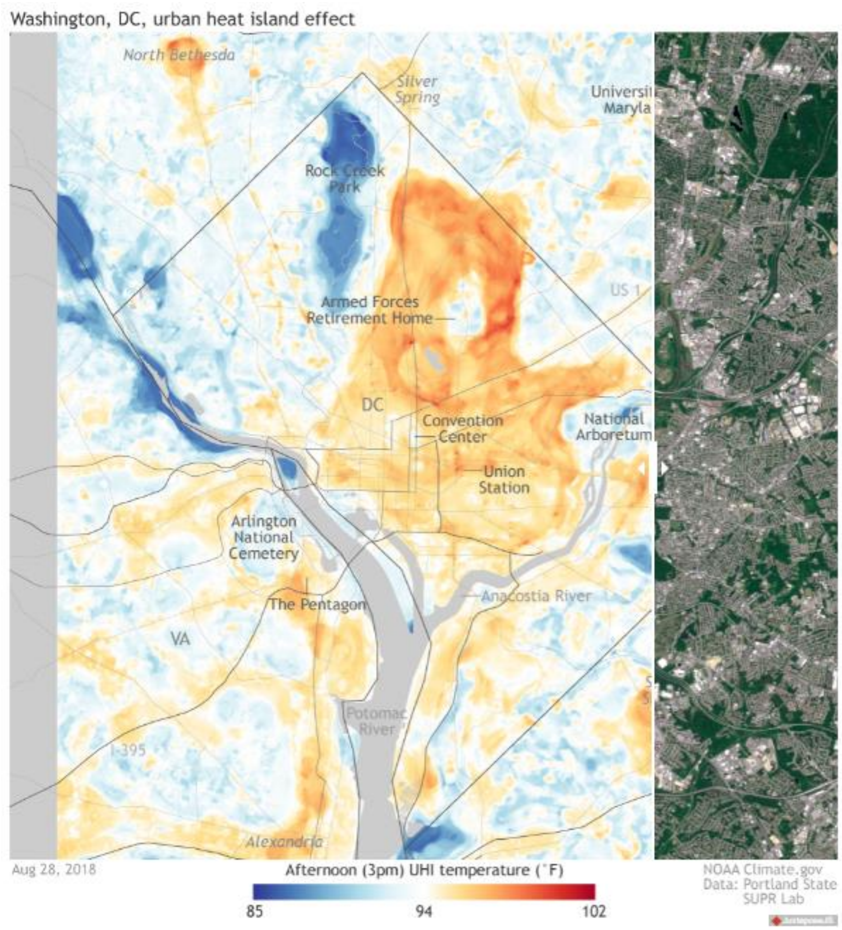
TEACHER NOTES

Source

- ✓ This activity is based on the activity "Greenhouse Effect) from the "Protect Your Climate" curriculum published by the Bay Area Air Quality Management District: https://www.baaqmd.gov/~/media/Files/Planning%20and%20Research/Climate%20Protection%20Program/protectyourclimate.ashx

What is a greenhouse?

- ✓ Students may have never seen a greenhouse, so be sure to show them a picture like this one so they have a frame of reference: https://heavy.com/wp-content/uploads/2020/04/greenhouse-kits-1.jpg?quality=45&strip=all&w=1100



3. **Introduce the experiment:** Tell students that to study the greenhouse effect that they learned about in their last class, and to test their ideas about what causes the urban heat island effect, they are going to do a series of experiments. Each group of students will do a different version of the experiment so that they can compare their results.

Pass out the Greenhouse Effect & Urban Heat Island sheet to students. Tell students that for this experiment, they are going to use a jar to represent the Earth's atmosphere. Ask students what properties of the jar are similar to the Earth's atmosphere, especially carbon dioxide (it lets sunlight in, but traps heat). Remind students that this is how the greenhouse effect gets its name. The jar is like a mini-greenhouse, just like the atmosphere of the earth acts like a greenhouse.

Show students one of the jars they will use for their experiment. Tell them that right now the jar is just an atmosphere. For their experiments, they need to have something to represent the Earth. Ask students what kinds of things they could put into the jar to act as different surfaces on Earth. If they get stuck, remind them of the surfaces they talked about during their warmup.

As students share ideas, write them down on chart paper or on the board. You can also ask about how they could represent specific things such as a roof or the ocean.

4. **Writing research questions:** Form students into groups, and have each group choose a surface that they will test. It is best if they all choose different surfaces so they can compare their results. From here, have students write a research question based on comparing their material to another material. For example, if students are using the black paper to represent pavement: "Does a dark surface cause the temperature to get higher than a light surface?" If students are new to writing research questions, you may want to write one together and then have them write their own questions in groups.

5. **Materials:** Review the materials list with students, and have them add any additional materials that they are going to use such as soil, grass, or black paper.

6. **Procedure:** In order for students to be able to compare results from their tests, they all need to agree on the same procedure. This experiment is relatively simple, so their procedure should consist of a few steps:
    - Put "surface" materials into the jar so that they are on the bottom. (have the class agree on whether the jars should be standing up or on their side)
    - Put lid on the bottle with the thermometer sticking out so it can be read
    - Leave bottle outside in a sunny place for 10-20 minutes (have students decide on a time)
    - Record the temperature of the air in the jar every 1-2 minutes (have students decide on a time)

    Have students write their procedure on their handout, including any additional steps.

7. **Variables and controls:** Have students fill in the variables and controls for their experiment. The independent variable is their surface, the dependent variable is the temperature, and the controls are the location of the jars, and the type of jars.

8. **Write a hypothesis:** Have students write a hypothesis about how the temperature in their jar will change compared to one or more of the other jars. Their hypothesis should be an answer to their research question. Make sure students are thinking about their hypotheses so they are logical. For example, ask them if they think dark surfaces heat up more than light surfaces?

9. **Build the setups:** Have students put together their jars. As they work, check to make sure the jars are the same except for the material they have put inside that will act as the surface.

TEACHER NOTES

Showing the Greenhouse Effect

✓ To demonstrate the greenhouse effect, run the experiment with a separate jar that is open to the air (lidless) to show that without the atmosphere, the temperature would be significantly lower. You may choose to do this variation alongside student experiments, or have each student group create a second jar that is the same without a lid.

Jar position options

✓ If jars are placed on their sides, there will be a larger area to use for their surface, so the temperature change will go faster. However, if you decide to use a lidless jar to demonstrate the greenhouse effect, the hot air will not be able to escape the jar as easily, and you will see less of a temperature difference.

TEACHER NOTES

Teacher tip

- ✓ Students sometimes struggle to make accurate thermometer readings if you are using alcohol thermometers. It is a good idea to practice reading a thermometer before going outside to collect data, and checking on students' measurements if you think they will have difficulty.

10. **Run the experiment:** Take the jars outside (or put them in a sunny location if you cannot go outside. Make sure to have students record the temperature at the exact intervals they have determined in their procedure. You can give each group a stopwatch, or use one stopwatch for the whole class and have them all take the temperature at the same time. Students should record their data in the "Jar 1" space on their data table.

11. **Data sharing:** Have students share data with groups that they have chosen to compare with. For example, if one group used a light surface and other group used a dark surface, or sand vs. grass., have them share data with the group that is using their comparison material. You may also want students to compare data from all the surfaces. If so, put all the data into a computer spreadsheet or on the board for students to copy. Have them write their comparison group data into the "Jar 2" space on their data table.

12. **Data analysis:** When students have collected all their data, return inside to have them do their analysis. They should start by finding the difference between the final and ending temperatures to see how much the temperature changed. You can also have them graph their data in a variety of ways: ex. bar graphs with the temperature change for each surface, or time vs. temperature line graphs. Make sure the graphical representation you choose is meaningful for the analysis.

13. **Discussion:** Have students share what they learned from their experiments. Use some or all of the questions below to help drive student thinking, but make sure that students are doing most of the talking, and make sure they are referencing their data. It will help for this if the data is visible somewhere in the classroom:
    - Which surface seemed to cause the temperature to rise the most? The least?
    - If you used an open-air jar, how did the closed jars compare to the open jar(s)?
    - Were you right or wrong in your hypotheses?
    - Are the surfaces that caused the temperature to rise the most similar or different in any way?
    - What do your results help you understand about the greenhouse effect?
    - What do your results help you understand about the urban heat island effect?

14. **Return to causation vs. correlation: urban heat islands and global temperature:** Ask students if they think urban heat islands are raising the global temperature (is one *causing* the other?). Students can make logical arguments on both sides (ex. if more heat is absorbed, more will be trapped, and that will raise temperatures). However, in reality, global heat islands do not trap nearly enough heat to raise global temperatures. They are *correlated* because as global temperatures increase, urban heat island temperatures also go up, but the *cause* of global temperature increases is the greenhouse effect, and the *cause* of urban heat islands is related to the types of surfaces in urban environments (as well as other factors). The only cause-effect relationship present is that when temperatures get hot in cities due to urban heat islands, people in those cities tend to use more electricity to cool the air, which does cause higher global temperatures (due to increased greenhouse gases being emitted to produce the electricity).

15. **Conclusion (formative assessment):** Have students complete the conclusions section of their experiment handout. The second question asks students why the air in some jars heated up more than others. After their discussion, students should be able to explain that some surfaces absorb more heat than others, and therefore heat up the jar more than others.

    The final question asks students to explain the urban heat island effect using their results. Students should be able to explain that there are more surfaces in urban areas that absorb a lot of heat, and therefore they raise the temperature in urban areas more.

Urban heat islands are complex

Urban heat islands are caused by more than just differences in surfaces. Large numbers of tall buildings can trap heat by slowing wind and acting as large heat sinks. Larger populations also add more heat to the air through the use of cars, air conditioning, and other machinery.

The effects of urban heat islands also go beyond higher temperatures. With higher temperatures come increase ozone levels (see the sidebar), and increased electricity demand for things like air conditioner. This increased electricity demand often results in additional greenhouses gases being released to the atmosphere, which accelerate climate change.

The Urban Heat Island Effect & Ozone Formation

- ✓ Ground-level ozone, an air pollutant that can irritate lungs and make breathing difficult, is formed by a chemical reaction that occurs in the presence of hot weather and sunlight. Another effect of the urban heat islands is an increase in ozone production due to increased temperatures.

Name ______________________________

The Greenhouse Effect & Urban Heat Islands

Research question: ______________________________

____

____

Materials

- ❒ Thermometer
- ❒ Jars with lids
- ❒
- ❒
- ❒
- ❒

Procedure

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________

Variables and controls

What is your independent variable? (What are you changing between your two setups?)__________

____

What is your dependent variable? (What are you measuring?)________________________________

What are you controlling? (What needs to be the same in both of your setups?) _________________

____

<u>Hypothesis</u>

Your hypothesis should be a logical answer to your research question based upon what you know about surfaces:

____

____

<u>Data</u>

Time	Jar 1:	Jar 2:
0 min		

<u>Analysis</u>

How much did the temperature change in Jar 1 (your jar)? ______________________________

How much did the temperature change in Jar 2? ________________________________

Conclusion

Was your hypothesis correct? _____________________________

Why did some jars heat up more than others? ____

____

____

____

____

Based upon your results, explain what causes the urban heat island effect.

____

____

____

____

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____

____

Activity 6 (Explore): Atmosphere in a Jar

Activity summary: In this activity, students investigate what the most common elements and compounds in the atmosphere are by digging into an atmospheric "soup" of molecules. They use ratios and proportional reasoning to relate the finding from their investigation to the atmosphere as a whole.

Standards Connection
SEP: Analyzing Data; Using Mathematics & Computational Thinking
CCC: Patterns

In advance: Gather the materials and setup the "Atmosphere in a Jar" activity. See teacher handout additional details.

Warmup: Show students the apple, and tell them to imagine that the apple is the Earth. If so, how big would the atmosphere be? (ex. would it extend out for 1", ½", etc.)

1. Answer: the atmosphere is the thickness of the apple's skin (you may choose to peel a piece of skin to show how thin it is)
2. When reviewing the answer with students, show them a photograph of Earth from space (such as the one below) to highlight how thin the atmosphere is.

2. **Frame the activity:** Remind students that the greenhouse effect is caused carbon dioxide and other gases in the atmosphere. In order for them to understand the problem of having too much carbon dioxide, they need to know more about what gases are in the atmosphere. Today they're going to study the atmosphere so they can understand how carbon dioxide affects the planet.

ACTIVITY DETAILS

Time: 45-60 minutes

Objectives

- ✓ Students will know what gases make up Earth's atmosphere and in what proportions
- ✓ Students will use sampling and quantitative analysis to estimate the composition of a mixture

Materials

- ✓ One apple (any kind)
- ✓ Apple peeler (optional)
- ✓ Beans for Atmosphere in a Jar (see teacher handout)
- ✓ Chart paper & markers (optional)
- ✓ One large, clear container
- ✓ Small cups – enough for one per student group
- ✓ Calculators
- ✓ Computer & projector

Handouts

- ✓ Atmosphere in a Jar activity sheet
- ✓ Atmosphere in a Jar summary questions (optional)

TEACHER NOTES

Differentiation

✓ If students are reluctant to share ideas in front of peers, have them write their answers on sticky notes or note cards. Make sure to get at least one answer from each student to support participation. You can also have students brainstorm first in groups, or have them write out a list before sharing.

Modifications

✓ The follow-up questions for this activity work well as a homework assignment.

Next steps

✓ If you plan to do the "How Much is a PPM" activity next, make sure to have students return their samples and keep the Atmosphere in a Jar nearby.

3. **Fact or Fiction. Gathering students' ideas**. Prepare a piece of chart paper (or a place on the board) to record student responses. Then ask them: what do we already know about the atmosphere of Earth? Record each answer on the board where all students can see. If students get stuck, prompt them with questions such as: "What do you think the atmosphere is made of?", "Is the atmosphere clean or polluted?", or "Where do the gases in our atmosphere come from?"
   - Don't tell students which statements are accurate or inaccurate, just focus on letting them share

   When students are finished sharing, tell them that you will come back to this list later as a class to see which statements we made about the atmosphere are actually facts and which are fiction

4. **Atmosphere in a Jar.** Follow the directions in the Atmosphere in a Jar teacher guide (see below).

5. **Atmosphere in a Jar follow-up questions (optional).** Use the Atmosphere in a Jar follow up question handout to help students think more about the process of sampling, the importance of using multiple samples, and why percentage is useful measurement when considering composition of a mixture.

6. **Formative assessment.** Let each student choose one fact or fiction from the list that has been decided. Have them write a short answer telling whether it is a fact or fiction, and supporting their answer using evidence from the activity. For example, if the "fiction" is "Our atmosphere is mostly oxygen" a student might write "Our atmosphere is mostly oxygen is fiction. Our atmosphere is only 21% oxygen. It is mostly made of nitrogen (78%).

Atmosphere in a Jar

TEACHER GUIDE

In this activity, students take samples of different beans and peas from a jar which represent the different molecules in Earth's atmosphere. By counting the numbers of each bean in their sample, and using proportional reasoning, they can determine what the different gases are in the atmosphere, and in what proportions.

Materials:

- Digital scale for measuring materials
- A large clear container big enough to hold all of the beans and peas required for an entire class, preferably one with a lid
- Different kinds of dried beans and peas[1]. See "preparation" below for approximate amounts and weights of different beans. You will likely need a whole bag of two different beans (ex. black beans and black-eyed peas) and a bag of mixed beans for the rest.
- Small sample cups for students (approx. 2 oz) – 1 per student group

Background information:
The vast majority of Earth's atmosphere is made up of just two gases: nitrogen or N_2 (78.09%) and oxygen or O_2 (20.95%). Trace gases such as argon (0.93%), carbon dioxide (0.04%), and others are also present in very small amounts. Air also contains a variable amount of water vapor, on average around 1% at sea level and 0.4% across the entire atmosphere.

Nitrogen: While nitrogen is important to human life, we cannot use the nitrogen in form it takes in the atmosphere. Bacteria take this nitrogen out of the air and "fix" it into a form that plants use. We therefore get the nitrogen that we need from the food that we eat.

Oxygen: The Earth did not always have so much oxygen in its atmosphere. It was not until about 2.7 billion years ago that blue-green algae (cyanobacteria) evolved the process of photosynthesis which began producing oxygen. Today, the majority of our oxygen is made by phytoplankton and other plants in the ocean.

Argon: Argon is a colorless, odorless, non-toxic, inert gas. Today, argon is commonly used in light bulbs. Argon is a great insulator used in double pane windows minimizes transfer of heat.

Water vapor: The amount of water vapor in the atmosphere is highly variable, based on different weather conditions. At low humidity, water vapor may only make up 0.2% of the atmosphere, but at high humidity, that percentage can get over 4%.

Carbon dioxide: Even though most animals produce carbon dioxide from cell respiration, and carbon dioxide is released by many human activities, this gas still makes up only a very small proportion of Earth's atmosphere (0.04%). However, even this small percentage can have large consequences for Earth's climate.

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[1] Beans and peas are suggested because they are inexpensive, easy to handle and clean up, and easy to distinguish from one another. Small Lego blocks, rice grains, beads, and popcorn kernels work equally well.

Preparation:

- Determine which beans will represent which gases in your "atmosphere". You will need 5 different beans, with the majority being the beans representing nitrogen and oxygen.
- Create your "atmosphere." These directions are based on the chart below which will provide a large enough atmosphere for a full class of students[2].
  - Count out and weigh 100 of your "nitrogen" beans
  - Multiply the weight by 39 (because you need 3900 beans) and record
  - Weigh out the recorded amount and add to your atmosphere container
  - Count out and weigh 100 of your "oxygen" beans
  - Multiply the weight by 10.5 (because you need 1050 beans) and record
  - Weigh out the recorded amount and add to your atmosphere container
  - Count and add 50 "argon" beans to the container
  - Count and add 50 "water vapor" beans to the container
  - Count and add 2 "carbon dioxide" beans to the container

Bean	Gas	Percentage	Number	Approximate Weight
Black bean	Nitrogen	78%	3,900	858g
Black-eyed pea	Oxygen	21%	1,050	220g
Pinto bean	Argon	1%	50	n/a
White bean	Water vapor	1%	50	n/a
Kidney bean	Carbon dioxide	0.04%	2	n/a
Total			**5,052**	

*Note: The percentages do not add up to 100% due to rounding and variability with respect to water vapor. See NASA's website for more information about Earth's atmosphere: https://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html

- Put a lid on your atmosphere container, and mix thoroughly. The atmosphere should look uniform when you are finished.

[2] If for any reason you choose to use different amounts based on the same proportions, be sure to mark down how many of each material (bean) you include in your "atmosphere" to use in later activities.

Leading the Activity:

- Show students the atmosphere jar and tell them that the materials in the jar represent the molecules that make up our atmosphere. In this activity, they are going learn about what gases make up out atmosphere by studying what's in the jar.

- Have students look at the jar and jot down (on their lab sheets) initial observations of what they see.

- Remind students that during their warm up, they mentioned some different gases that they think are in Earth's atmosphere. Tell them that each bean (or other material) in this jar represents one molecule of a gas in our atmosphere. Note: If this is the first time you have used the word "molecule" with students, take a moment to discuss what this word means.

- Tell students that the amount of each bean in the jar is proportional to the amount of the actual gas it represents in the atmosphere. In other words, if there is a gas that makes up 10% of the gases our atmosphere, that bean makes up 10% of the beans in the jar. We are going to use this information to figure out what gas each bean in the jar represents.

- Ask students if they would like to take the rest of the week to count all the beans in the jar so they can find out how many of each bean there is. When they (hopefully) reject this idea, tell them that scientists use a technique called "sampling" to count things when there are a lot of things to count. Instead of counting all the beans, we will take "samples" from the jar and count those instead. As long as the samples are similar to the whole jar, we can use our samples to calculate what percentage of each bean there is in the jar.

- Go over the sampling and counting procedure that students will do in groups. You may want to do one as an example:
  - Take a sample cup and scoop a full cup of beans from the jar
  - With your group, separate all the different types of beans
  - Count the number of beans of each type and record the names and numbers on your data sheet.
  - Make sure to hold up each bean for students and tell them what it is called so they can aggregate data together with the class.

- Break students into groups and have them collect their samples and count their beans.
  - Teacher tip: when counting, have students make groups of 10 with their beans so that they don't lose count.
  - Teacher tip: Because there are so few carbon dioxide beans, try to ensure that at least one group gets one.

- Once all students have finished counting their beans, have them total the number of beans in their sample and write the total on their data sheet. They should also fill in the column for ratio of number to total.

- Discuss with students how to calculate the percent of each bean that is in their sample compared to the whole (molecule total/overall total x 100). Once students understand the procedure, have them calculate the percentage of each bean in their sample and write it on their data sheet.
    - Teacher tip: Calculating percentages is a 7^{th} grade standard in many states, so students may or may not have learned how to do this already.

- Have groups share aloud what percentages they got for each bean. There will be differences, so ask them why they think their numbers are different. Use this opportunity to discuss that sampling does not give us a "correct" number. It is like an estimate of the percentage. Scientists use sampling because it is much faster than trying to count all the beans in the jar. Because each group had a slightly different sample, they got different percentages. Ask students if they think counting more means or less beans would give them a more accurate sample. Use discussion to build student understanding that larger samples provide better estimates of the "real" number they are trying to estimate.

- Ask students how they can use their data to get the best estimate of the actual percentages. Use discussion to help them realize that if they combine their data, they will have a better estimate than if they use just their own group's data. Have them pool their data (using a spreadsheet on a computer, a whiteboard, etc.). Just pool the raw numbers (not the percentages). Have students record this information in the "class data" portion of their data sheet.

- Have students write the ratio of each number of beans to the total using the class data. They should then calculate the percentage of each bean, and record their percentages on their data sheets. Take a moment when students are finished to have them compare the class data with their own data. Some things will likely be higher, and others will be lower.

- Once all the data has been calculated, share the list of gases in the atmosphere with students. See if they can guess which material goes with which gas in the space on their data sheets.

- Share the correct answers about which material goes with which gas. Have students share whether they were surprised or not. Most students will likely be surprised that nitrogen (a gas they are not very familiar with) makes up the largest part of Earth's atmosphere, while carbon dioxide and water vapor (gases they are likely more familiar with) make up such a small part.

- Optional: Have students complete one or more of the follow-up tasks related to this activity:
    - Answer the summary questions (see handout below)
    - Create a bar graph or pie chart showing the make-up of Earth's atmosphere
    - Calculate the volume of each gas we breathe each day (see handout below)

STUDENT HANDOUT

Name ______________________________

Atmosphere in a Jar Data Sheet

Initial observations: what do you notice about the materials in the jar?

Group directions:

1. Take a sample from the "atmosphere" jar using your sample cup
2. Separate all the different types of beans in your sample
3. Count the number of each type of bean
4. Record the name of the bean and the number in the data table
5. Add up the total number of beans in your sample, and write it on your data table
6. Write the ratio of the number of beans in each sample to the total
7. Calculate the percentage of each bean in your sample using the formula below:

$$Percent\ of\ total = \frac{number\ in\ sample}{total} \times 100\%$$

My group's sample data:

Material (bean)	**Number in sample**	**Ratio of number to total**	**Percent of total**
Total			

Class data:

Material (bean)	Number in sample	Ratio of number to total	Percent of total
Total			

What gas do you think each bean represents?

Material (bean)	My guess	Actual gas	Percentage of Earth's atmosphere

Name ______________________________

STUDENT HANDOUT

Atmosphere in a Jar Follow-Up Questions

Answer the questions below based on the Atmosphere in a Jar activity.

1. Which estimate of the gases in the atmosphere do you thinks more accurate?

   My group's estimate   The class data estimate

   Why do you think your choice is more accurate?

   ____
   ____
   ____
   ____

2. If the beans in the jar were not mixed up before you took your sample, do you think you could make a good estimate of the gases in the atmosphere? Why or why not?

   ____
   ____
   ____
   ____

3. Why is it more useful to know the percentage of each gas in the atmosphere instead of the amount of each gas? Hint: When you take a quiz, it is more useful to know how many questions you got right, or the percentage of questions you got right?

   ____
   ____
   ____
   ____

Activity 7 (Elaborate): How Much is a PPM? (optional)

ACTIVITY DETAILS

Time: 30-45 minutes

Objectives

- ✓ Students will develop an intuitive and mathematical sense of the unit parts-per-million
- ✓ Students will understand that very small amounts of pollution can have a big effect on the atmosphere

Materials

- ✓ Atmosphere in a Jar (from previous activity)

Handouts

- ✓ How Much is a PPM?

Activity summary: In this activity, students will learn about the concept of parts-per-million (ppm) in order to understand how small amounts of pollution can have a large effect on the environment. They will do this by returning to their Pollution in a Jar activity and using mathematical reasoning skills.

Standards Connection

DCI: ESS3.C – Human Impacts on Earth Systems

SEP: Using Mathematics & Computational Thinking

Warmup: How long would it take you to count to a million?

- Some students may try to calculate, others may guess. Both methods are fine because the goal of this lesson is to help students develop both a mathematical *and* an intuitive sense of large numbers.
- After students have reached their answers, go over how to find out the answer (assuming one counted number per second):

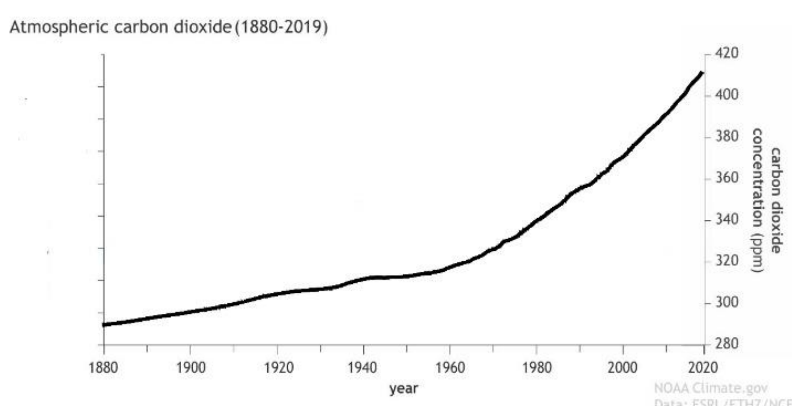
$$1{,}000{,}000 \text{ seconds } \times \frac{1 \text{ minute}}{60 \text{ seconds}} = 16{,}666 \text{ minutes}$$

$$16{,}666 \text{ minutes } \times \frac{1 \text{ hour}}{60 \text{ minutes}} = 277 \text{ hours}$$

$$277 \text{ hours } \times \frac{1 \text{ day}}{24 \text{ hours}} = 11.6 \text{ days}$$

- See how this compares with students' estimates/calculations. Use this to start reinforcing for students how large 1 million is.

1. **Frame the Activity**. Show students the graph from Activity 4 (below) that shows the amount of carbon dioxide levels in the atmosphere:



Point out that the scale for carbon dioxide on the right side is in parts-per-million. Ask them if they've ever seen this unit before. It is unlikely – this is a pretty unusual unit! Tell students that today they're going to think about how much carbon dioxide is too much, and how low it needs to be to slow down or stop the global temperature from rising.

2. **Pollution in a Jar.** Take out the atmosphere in a jar from the previous activity, and remind students of what it represents. Hold up one bean of carbon dioxide (whatever bean you chose to represent it), and remind students that this bean represents carbon dioxide. Return to the graph of carbon dioxide levels and point out to students that the current level of carbon dioxide in the atmosphere is about 414 parts per million (for current levels visit https://www.co2.earth/). That would mean that there would be 414 beans in a jar that had a million beans in it. Ask students how many beans that would be in their jar that has far fewer beans. Have students record their guesses for later.

3. **Understanding parts-per-million:** Hand out the "How Much is a PPM?" sheet to students, and have them read the first section. Use a reading strategy to help students focus on key points and questions they have about of the reading. When students are done, have them share key points, and use peer discussion to help answer any questions they have.

4. **Animated Part-per-million (optional).** Show students the animated video "How to Visualize One Part Per Million" found at: https://www.youtube.com/watch?v=aa-m8a-jZ0k

5. **Return to Pollution in a Jar.** Take out the atmosphere jar and remind students of their guesses from earlier in class about how many "beans" of carbon dioxide would need to go into their jar to make it equal to 414 parts per million. See if the students want to revise their estimates based on the reading.

   Read the next section of the handout together ("How much carbon dioxide is in our jar?"). Have students write the fraction for the amount of carbon dioxide in the atmosphere on their papers in the box.

   Note: You will need to adjust the fractions in the next section if you used a different amount of beans than the suggested amount.

TEACHER NOTES

Modifications

- ✓ This activity provides many opportunities to incorporate math. Feel free to take advantage of this fact by building in additional problems that relate to the math students are currently learning.
- ✓ There are many different mathematical terms used in this lesson which can be interchanged (ex. fraction, ratio, proportion). If students are new to any these terms, make sure students understand them well enough that they do not interfere with their understanding of the lesson.

Teacher Tip

- ✓ The jar actually has about 5,052 beans in it (if you used the amounts listed). This is rounded to 5,000 for this activity to simplify the math somewhat. The result will ultimately be the same.

TEACHER NOTES

Teacher Tip

- ✓ The goal of this part of the activity is to help students understand the idea of air pollution from a proportional perspective, and to realize how a very little amount of air pollution can make a huge difference in air quality.

Next, ask students how they could figure out what the fraction would be if they put one bean of carbon dioxide in their jar. Ask students to write the fraction representing the ratio of pollution to air in the jar in the box on their paper next to the carbon dioxide amount like this:

$$\frac{414}{1{,}000{,}000} \qquad \frac{1}{5{,}000}$$

Have students turn to a partner to determine which fraction is larger.
If they get stuck on this, suggest that they multiply the second fraction by 414/414 to make equivalent numerators.

After a few moments, have them share their findings. When they agree that the "jar" fraction is smaller (414 out of 2,070,000 is less than 414 out of 1 million), have them write an inequality symbol between the fractions to show this.

$$\frac{414}{1{,}000{,}000} > \frac{1}{5{,}000}$$

6. **Making sense of the fractions.** With their partners, have students determine what this means. Does one bean of carbon dioxide in the jar mean it is more or less than the amount in the atmosphere? Bring the class back together, and let them discuss until they agree that one bean in the jar is not enough because it is still less than the amount in the atmosphere.

7. **Finding equivalent ratios/fractions:** Tell students that they know they need more than one bean, but how many do they need? To figure it out they need to make equivalent fractions. Write this on the board and have them add it to their papers (if they are familiar with variables, you can use "x" instead of the "?"

$$\frac{414}{1{,}000{,}000} = \frac{?}{5{,}000}$$

Ask how they can figure out what goes in the space with the question mark. There are many different ways to solve this (ex. cross multiply and divide). To continue with finding equivalent fractions, you can suggest that they can divide the top and bottom by the same number to get an equivalent fraction. What number do you need to divide 1,000,000 by to get 5,000? They can solve this with guess-and-check, or by dividing. Give partners time to figure out what the answer is. When they figure it out that it is 200, ask them what the numerator in the equivalent fraction should be (2.07). Have them write 2.07 into the space where the question mark is.

TEACHER NOTES

Ask students how many carbon dioxide beans this means they should put into their jar (2). Ga back to students' guesses from earlier in the class to see if anyone was right (or close).

8. **Reflection: such a small amount:** Ask students if they are surprised that such a small amount of carbon dioxide can have such a big effect on the environment. Take a moment to have students consider this effect. You may want to have them make an analogy to their own lives or to their experience (has one day in their life been very important? Can one person make a difference in the lives of millions of others?)

9. **Formative assessment:** Tell students that the carbon dioxide level in the atmosphere 100 years ago was 303 ppm. Have them write this as a fraction, and see if they can figure out how many beans (or parts of beans) they would need in their jar if it was 100 years ago.

$$\frac{303}{1{,}000{,}000} = \frac{1.5}{5{,}000}$$

There would be about 1.5 beans of carbon dioxide in the jar 100 years ago.

Name ____

STUDENT HANDOUT

How Much is a PPM?

The current amount of carbon dioxide in the atmosphere is about 414 parts-per-million (ppm). That means that there are 414 molecules of carbon dioxide for every million molecules of gas in the air. Parts-per-million is a unit just like inches or miles or meters.

We can also write parts-per-million as a fraction. Look at the three fractions below:

1 percent (1%) = $\frac{1}{100}$ $1 \text{ ppm} = \frac{1}{1{,}000{,}000}$ $414 \text{ ppm} = \frac{414}{1{,}000{,}000}$

One percent pollution would mean 1 molecule of pollution for every 100 molecules of air. 1 ppm is 1 molecule of pollution for every 1,000,000 molecules of air, so 414 ppm is 414 molecules of pollution for every million molecules of air.

414 ppm seems like a big number, but parts-per-million is a pretty small unit. How small is it really? Think how long one day is. One day in a million is the same as one day in 2,737 years, so 414 parts per million is like 1 year in 2,413 years!

<u>How much carbon dioxide is in our jar?</u>

Think about our atmosphere in a jar. If we want to show how much carbon dioxide is in our atmosphere, we would need to put 414 beans in a jar with a million beans. But our jar has far fewer than a million beans in it! In fact, our jar only has about 5,000 beans. So how many beans of carbon dioxide do we need to put in our jar?

How many carbon dioxide beans should go in our jar?

Activity 8 (Elaborate): Climate Change & Resilience

Activity summary: In this activity, students learn about how the greenhouse effect connects to climate change. They also interpret graphs of predicted CO_2 levels and sea-levels to make the connection between different possible climate change scenarios. Finally, they learn about climate resilience, and watch a video about New Orleans to learn about how they can build flood resilience into their own community.

Standards Connection
DCI: ESS 3.D: Global Climate Change
DCI: ESS 3.C: Human Impacts on Earth Systems
SEP: Analyzing Data
CCC: Patterns

Warmup: When you hear the words climate change, what do you think of? What do you already know about climate change?

- The purpose of this warm up is to activate students' prior knowledge about climate change, and provide some information to the teacher about what students already know. Because students will be learning more about climate change during the activity, don't spend too much time diving into students' prior knowledge.
- If students asked any questions in Activity 1 related to climate change, be sure to point them out before continuing.

1. **Frame the Activity**: Remind students of the sunny day flooding activity (Activity 2) where they looked at how different amounts of sea level rise would result in different amounts of flooding. You may want to go back to the website quickly to show them: http://coast.noaa.gov/slr. Tell students that scientists don't know how much sea level will rise in the future, because humans have the ability to prevent changes like this. Today they are going to think about different sea-level rise scenarios to see how they connect with different amounts of greenhouse gases like carbon dioxide, and what they can do to protect their community from climate change.

2. **Reading: Climate change:** Hand out the What is Climate Change? reading to students. Have them read the passage and answer the questions. When they are done, lead a short discussion about the difference between the greenhouse effect and climate change. The key takeaway is that the greenhouse effect is a natural process, while climate change is the result of humans increasing the greenhouse effect by adding additional greenhouse gases to the atmosphere.

ACTIVITY DETAILS

Time: 45-60 minutes

Objectives

- ✓ Students will understand the concept of climate change and how it is tied to atmospheric CO_2 concentration
- ✓ Students will understand the concept of climate resilience and how it applies to sea level rise

Materials

- ✓ Computer & Projector
- ✓ Speakers (for video)

Handouts

- ✓ What is Climate Change?
- ✓ Climate Resilience and Sea Level Rise

TEACHER NOTES

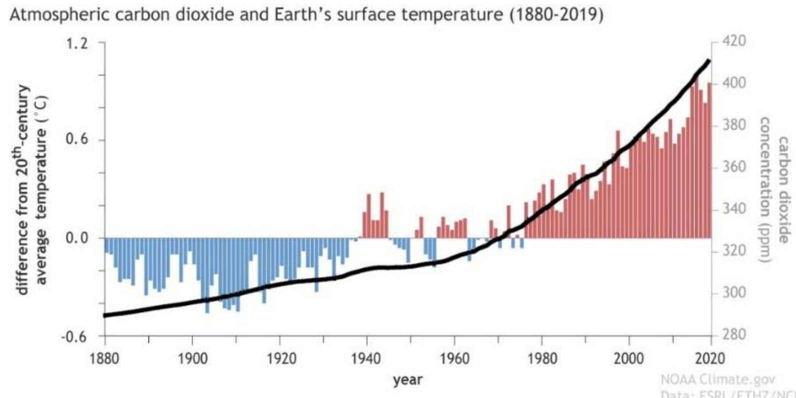
Climate Change Data Source

- ✓ A huge quantity of data, analysis, and predictions about climate change come from the UN's Intergovernmental Panel on Climate Change (IPCC) which is the foremost authority on climate change. Their most recent major report is the 2014 Synthesis Report (AR5). Their next reports (AR6) are expected in 2021-2022.

Teacher Tip

- ✓ The RCPs in these graphs refer to "representative concentration pathways" which provide a few possible scenarios from among the many possible outcomes.

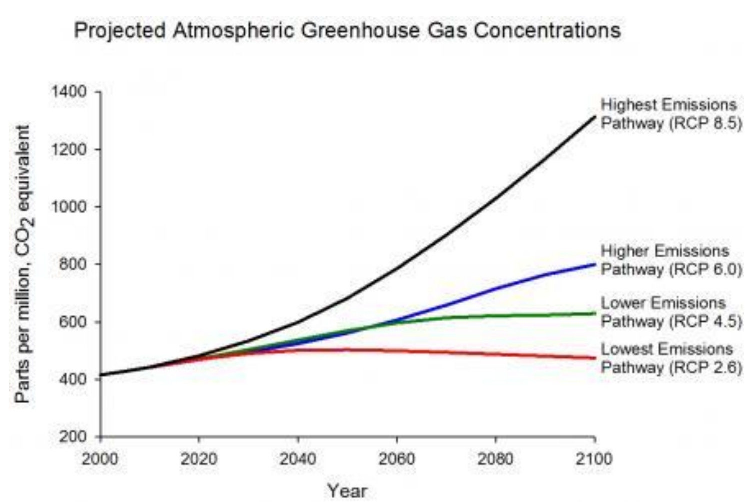
3. **How much is too much?** Show students the graph of the carbon dioxide concentration and global temperature:



Ask students what they think will happen to the temperature if the carbon dioxide levels continue to go up? (It will continue to get hotter). That might be an easy question, but what about if the carbon dioxide level goes down? For example, what if it goes down to 400 ppm? Will the temperature still go up? It might, because 400 ppm is still much higher than the concentration of CO_2 used to be. What scientists right now are trying to figure out is, how much carbon dioxide is too much? How far do we have to make it go down to get the temperature back to normal?

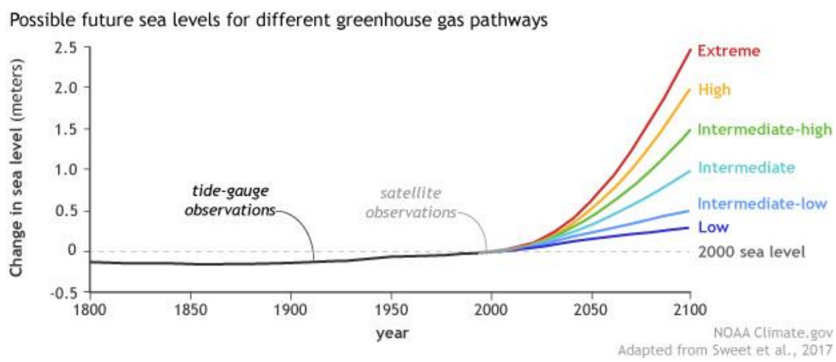
Tell students that in the next part of their activity, they are going to look at different climate change scenarios based on how much the greenhouse gas level goes up or down.

4. **Introducing the climate change scenarios:** Have students turn to the back of their reading to look at the graph, and project it so students can see it in color.



Tell students that scientists create models to predict how the climate will change based upon how much greenhouse gas is in the atmosphere. However, the scientists don't know how much greenhouse gas there will be, so they make different predictions for different amounts of gas. This graph above shows the amount of greenhouse gas (in ppm) for each scenario. Have students mark on their graphs the worst-case scenario (RCP 8.5), the mid-case scenarios (RCP 4.5 & RCP 6.0) and the best-case scenario (RCP 2.6). Ask students why they think we have these different scenarios (it is based on what decisions we make to stop polluting the air with CO_2 and other greenhouse gases).

5. **Sea-level rise scenarios:** Have students look at the graph that shows "Possible futures sea levels for different greenhouse gas pathways" and project it so they can see the colors:



Ask them what similarities they see in this graph compared to the last one they looked at (it is line graph, it shows a similar time period, it has a few different lines that split apart as you go into the future). Ask students why there are different scenarios for sea level rise. (it also depends on what decisions we make to stop emitting greenhouse gases). Ask which greenhouse gas level goes with which scenario (note that there is not an exact match, but the scenarios are similar).

Have students use the graph to determine what the sea level rise prediction is for three different greenhouse gas levels. Make sure they change from meters to feet for their answers.

6. **Introducing resilience:** Write the word "resilient" on the board and ask if anyone know what the word resilient means. Have students share what they know about the word resilient. Use what students know to introduce the definition of community climate resilience: "the ability of communities to prepare for, respond to, and recover from hazardous events and adversity related to climate change."

TEACHER NOTES

Modification

- ✓ If the school community is in an area that is at risk from flooding due to climate change, feel free to change the formative assessment scenario to be about the school community. In Activity 10, students will directly address how to address climate change, including through changes in their personal lives and by building community resiliency.

Ask students if they have ever recovered from adversity. Have a few students share their experiences if they are interested (as appropriate). Use this to begin making a connection between personal resilience and community climate resilience.

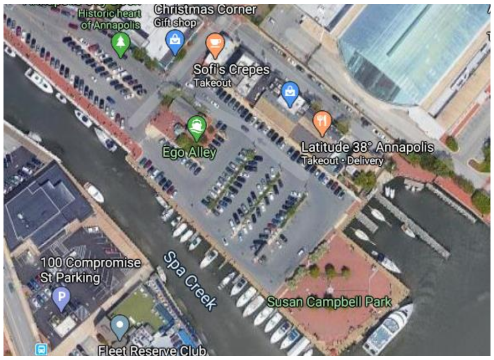
7. **Resilience example:** Hand out the Climate Resilience and Sea Level Rise sheet to students. Tell students that communities that are facing rising sea levels can prepare to deal with the changes. In just a moment, they are going to watch a video about a city that is dealing with flooding from rising sea levels and also extreme weather. During the video, they should take notes on their handouts about what the people in the city are doing to build resilience from flooding.

Show the video: Sea Level Rising: Living With Water from 0:48 to 7:09. The video can be found at: https://www.pbs.org/video/sea-level-rising-living-with-water-involp/. Some solutions for resilience seen or mentioned in the video:

- ✓ Elevation (building houses up off the ground)
- ✓ Plant rain gardens
- ✓ Plant orchards
- ✓ Build canals to circulate water around the city
- ✓ Plant specific plants in low areas that will help the ground absorb water
- ✓ Build “blue ways” to channel water

After the video, have students share some of the things they wrote down that New Orleans is doing to build climate resilience.

8. **Formative assessment:** Have students complete the prompt on making their community more resilient to flooding from climate change. You can also show them Google Street View pictures of this community to give them a better sense of what it is like. Much of this area will be under water given the intermediate sea level rise scenario:



Possible student answers:

- Build a wall along the water to keep out the rising water level
- Replace some of the pavement with grassy areas that can absorb water from flooding
- Elevate the building (if possible) or raise the floor level to keep water out in case of a flood
- Move these stores to a different part of the city that is less prone to flooding and use this space for something else

TEACHER NOTES

Extension

✓ The Urban Sustainability Directors Network has created a series of "games" designed to teach people about how to build climate resiliency into their community plans. You can check out their three scenarios (Game of Floods, Game of Extremes, and Game of Heat) here: https://www.usdn.org/projects/climate-trainings.html

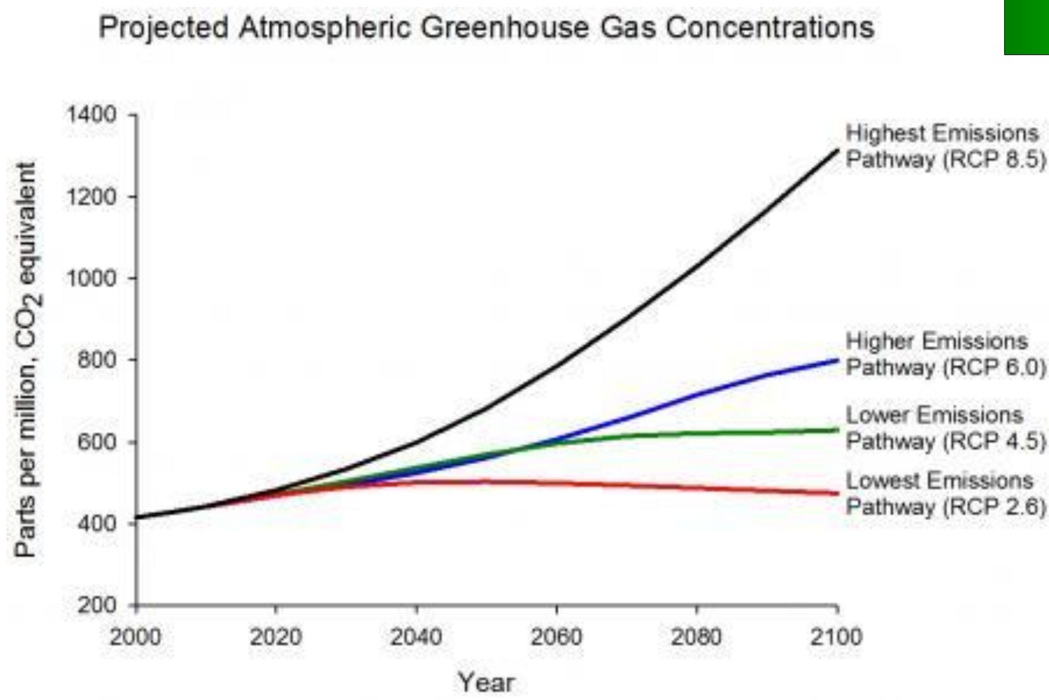
STUDENT READING

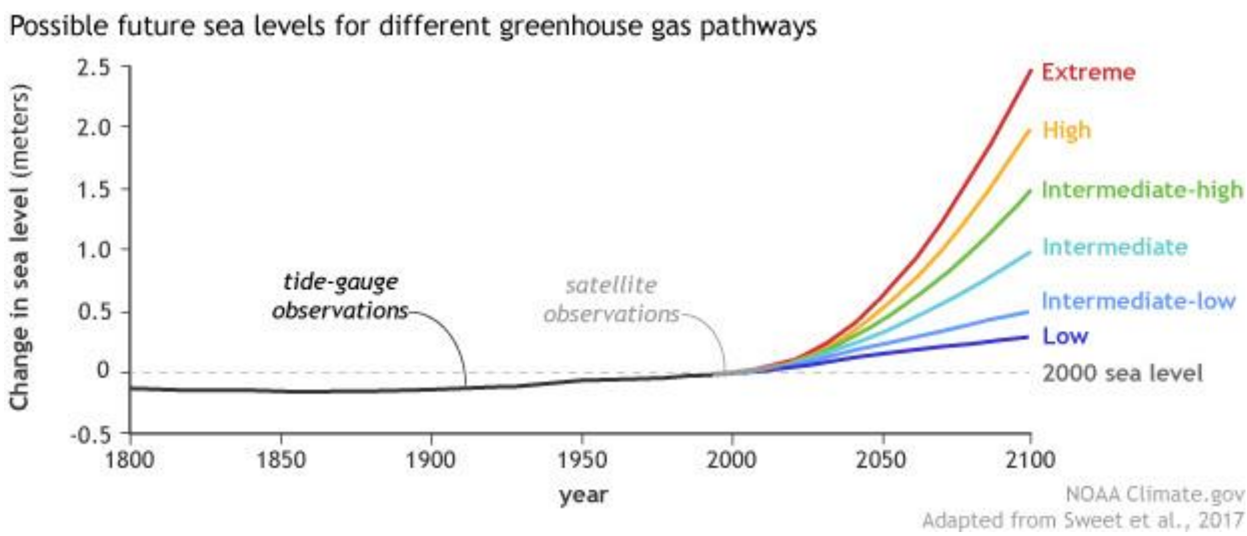
Name ______________________________

What is Climate Change?

The greenhouse effect is a process that occurs when certain gases in the Earth's atmosphere trap heat and cause the planet to get warmer. Carbon dioxide (CO_2) is the most important greenhouse gas, but there are other greenhouse gases in the atmosphere such as water vapor, methane, and nitrous oxide.	What are the major greenhouse gases?
When the temperature on the planet goes up, it causes more than just hotter days. There are a lot of different effects that are caused by a warmer Earth. Climates across the planet will be different, so we call these effects "climate change." Climate change involves changes in long-term weather patterns including temperature, rainfall, and storm activities.	What is climate change?
There are many effects from climate change. Rising sea levels are one example. Melting polar ice in both the Arctic and Antarctic is another. As temperatures rise, we expect there will be more droughts and heat waves, which can lead to wildfires. Many places in the United States will get more rain, although some will get less. Hurricanes are also expected to get stronger.	Name three effects of climate change:
Even though the effects of climate change can feel frightening, there is reason to be hopeful! Millions of people around the world are working to help stop climate change by reducing the amount of carbon dioxide in the atmosphere. Because greenhouse gases are often produced in power plants and vehicles, we can all do our part to reduce climate change by using less electricity, and riding or driving less in cars and trucks.	Name two ways that you can help stop climate change:

STUDENT HANDOUT





Note: 1 meter is about 3 feet.

What is the predicted change in sea level in feet for the extreme scenario?	
What is the predicted change in sea level in feet for the intermediate scenario?	
What is the predicted change in sea level in feet for the low scenario?	

Name ______________________________

Climate Resilience & Sea Level Rise

Community climate resilience: the ability of communities to prepare for, respond to, and recover from hazardous events and adversity related to climate change.

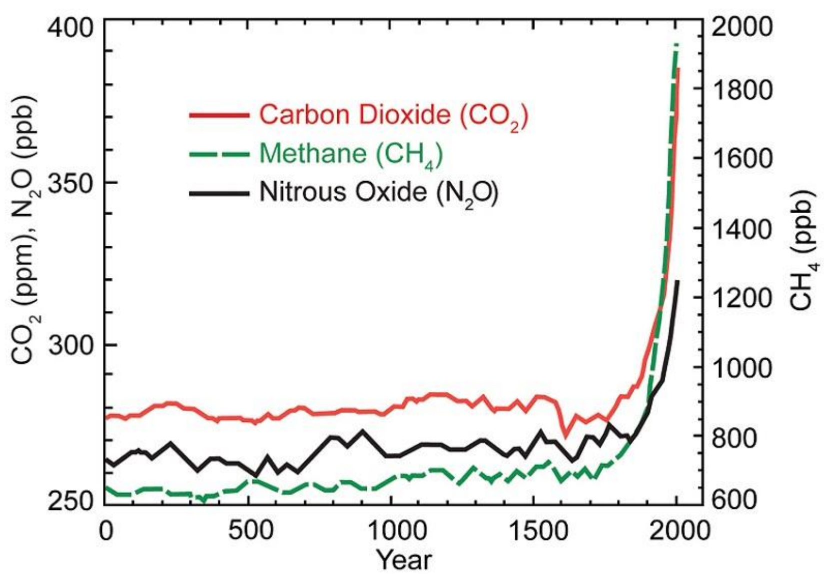
What kinds of things do the people in the video do to prepare for flooding?
Think back to the sea-level rise scenarios we studied in Annapolis. Imagine that you are a business owner with a store that is in the light blue zone. You want to prepare for the "intermediate" climate change scenario. What kinds of things can you do to make your community more resilient to climate change?

Activity 9 (Elaborate): CO_2 Sources & Solutions

Activity summary: In this activity, students learn about where fossil fuels come from, and they make the connection that burning fossil fuels (largely in power plants and vehicles) is what is increasing the amount of carbon dioxide and other greenhouse gases in the atmosphere. They research local sources of greenhouse gases, and discover that sources of greenhouse gases are also the sources for other air pollutants. Finally, students start brainstorming ways that they can reduce the amount of carbon dioxide they put in the atmosphere.

Standards Connection
DCI: ESS 3.D: Global Climate Change
DCI: ESS 3.C: Human Impacts on Earth Systems
SEP: Analyzing Data
CCC: Cause & Effect

Warmup: Show students this graph of greenhouse gas concentrations over the last 2000 years:



At this point, they should be relatively familiar with graphs showing greenhouse gas concentrations, but make sure they understand what the graph is showing. Then ask them what they think happened to make the graph go up so much in the last 200 years.

- Use this warmup to gauge students' familiarity with things like the industrial revolution and human activities like combustion engines, power plants and factories that produce greenhouse gases. These are all topics they'll explore during this activity. If these ideas are new to them, then use the warmup as a way to frame what they'll be learning about today. They will come back to this graph in their formative assessment, so don't take the time now to go into a deep explanation.

ACTIVITY DETAILS

Time: 45 minutes

Objectives
- ✓ Students will understand where fossil fuels come from
- ✓ Students will understand how carbon dioxide gets into the atmosphere from fossil fuels
- ✓ Students will identify local sources of greenhouse gas emissions
- ✓ Students will brainstorm ideas for keeping carbon dioxide out of the atmosphere

Materials
- ✓ Computer & projector
- ✓ Speakers (for video)
- ✓ Student computers (optional)
- ✓ Plain paper

Handouts
- ✓ Carbon dioxide and Fossil Fuels graphic organizer

TEACHER NOTES

Teacher Tip

✓ Students learned a little bit about where greenhouse gases come from in Activity 2, so try to tie in anything they remember from that activity (or previous modules) about where pollution comes from.

Teacher Tip

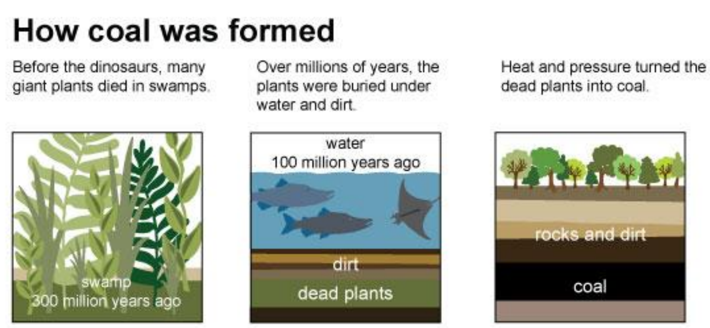
✓ If you have previously studied the carbon cycle with students, this would be a great opportunity to make a connection back to it.

1. **Frame the Activity**: Tell students that as humans, we can deal with climate change in two big ways: we can plan for resilient communities that can decrease the effects of climate change, and we can slow down the rate of climate change by limiting the amount of greenhouse gases we put in the air. During the last activity, they focused on resilience, so today they are going to learn about how to limit greenhouse gas emissions.

2. **Introduction to fossil fuels:** Have students turn to a partner and discuss for a brief moment if they (personally) can create carbon dioxide. When you come back together as a class, have them share what they decided. At least some students should remember that we as humans breathe out carbon dioxide all the time. Each person exhales over 800 pounds of carbon dioxide every year! Tell students that carbon – part of carbon dioxide – is an element that is a very important part of living things. Every living thing on the planet is made of carbon and other elements. So where is all this carbon dioxide coming from that is causing climate change?

   Pass out the Carbon Dioxide and Fossil Fuels graphic organizer, and ask students what goes in the first box (carbon) and have them fill it in.

   Show students the graphic below and have them read through it.



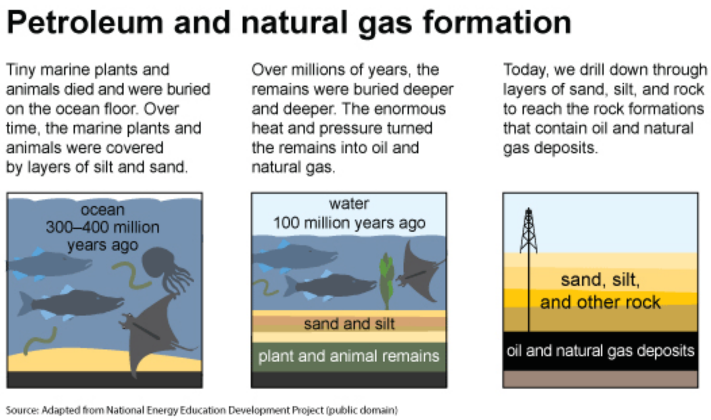
Source: Adapted from National Energy Education Development Project (public domain)

Use questioning to help students understand that coal is mostly made of carbon. For example:

- Based on this graphic, what coal is made from? (dead plants).
- What element did we say is a big part of plants? (carbon)
- What element do you think coal is mostly made of? (carbon). The carbon content of coal varies, but coal commonly has a carbon content of 75%.

TEACHER NOTES

Next, show students this graphic that shows how oil and natural gas are formed. The processes are very similar except that oil and natural gas formation mostly involves marine animals and plants.



Ask students what should go in the second line (plants & animals) and third line (coal, oil, and natural gas) in their graphic organizers and have them fill it in.

3. **What do we do with fossil fuels?** Ask students what we do with things like coal, oil, and natural gas to get the energy out of them? (We burn them). Show students the picture below, which shows burning coal:

Tell students that we burn fossil fuels in power plants to generate electricity and to power things like cars and trucks. But when we burn fossil fuels, the carbon in the fuel combines with oxygen to make carbon dioxide. That is the carbon dioxide that is causing climate change.

Ask students what should go in the fourth line (burn them) and fifth line (carbon dioxide) of their graphic organizers, and have them fill it in.

TEACHER NOTES

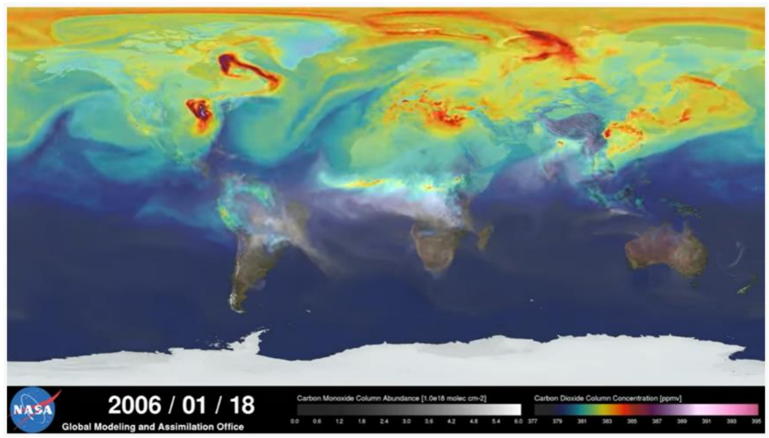
Additional Media

- ✓ This video from California Academy of Sciences has a great youth-led explanation of how fossil fuels and made and what problems they pose: https://www.calacademy.org/educators/whats-the-deal-with-fossil-fuels
- ✓ Vox produced an alternative version of NASA's Earth and CO_2 video which highlights some important details. You may wish to show that video instead of NASA's original: https://www.youtube.com/watch?v=fJoo2E4d8Ts

Modification

- ✓ If student computers are available, have students use them to look up the information in the spreadsheet themselves.

4. **Earth and carbon dioxide:** To give students a sense of what carbon dioxide in the atmosphere looks like, show them this very cool short video from NASA which models carbon dioxide emissions and dispersion during the course of a year: https://www.youtube.com/watch?v=x1SgmFa0r04. Before playing the video, asks students to keep an eye out for where the most carbon dioxide emissions are coming from (North America, Europe, and Asia)



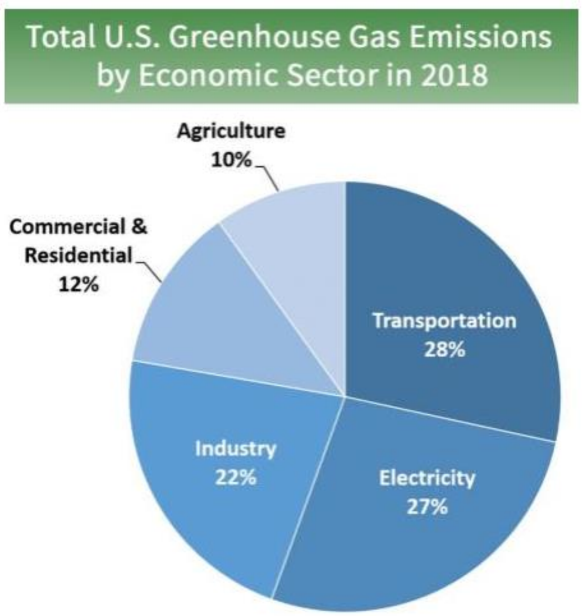
If you have already studied photosynthesis, this video also provides an opportunity to talk about why CO_2 levels drop in the summer (in the Northern Hemisphere) and go up in the winter.

5. **Local sources of greenhouse gases:** Ask students if they think there are any sources of greenhouse gases like power plants and factories in the area. After they have had a chance to think about it, go to: https://tinyurl.com/DCMetroAirPollution and display it for students to see. Go to the tab for greenhouse gases and sort the total emissions column Z→A. This will bring up a list of the largest greenhouse gas emitters in the DC, MD, VA, WV area. Have students turn to the back side of their handout, and answer the first two questions together:
   - The top 10 sources of greenhouse gases in the area are all power plants (electricity generation)
   - Other sources in the top 30 are factories/mills (pulp & paper, cement, and chemical manufacturing)

   Next, look up local sources of greenhouse gases. You can do this by filtering the list for a particular county or zip code. To filter, click the little triangle at the top of the column you want to filter, click "clear", then click on the individual county or zip code to add it to the list. You can also sort the column and search for your county or zip code. Have students identify the top local sources of greenhouse gases and them to their papers. Ask students if they've ever heard of these sources.

6. **Greenhouse gases and other air pollutants:** Switch over to the "Criteria pollutants" tab and sort the total emissions column by Z→A. Click the emissions units filter and uncheck the "tons" option so the list is sorted by the highest emissions sources. Tell students that this is a list of different kinds of air pollutants that are called criteria pollutants. Some criteria pollutants are also greenhouse gases, and some are not. Have students look at the list of the top emissions sources. Do they notice any similarities? You may want to go back to the original greenhouse gas emissions list (not the local list) so students can compare. What do they see? (the top sources are mostly the same). Ask them what this tells them about how different kinds of air pollution are related (many different kinds of air pollution come from the same sources). Have students answer questions 4 and 5 on their handouts.

7. **What can we do?** Show students the infographic below, and ask them which sector they think most of the greenhouse gases *they* add to the atmosphere come from (most likely electricity and transportation).



Total Emissions in 2018 = 6,677 Million Metric Tons of CO_2 equivalent. Percentages may not add up to 100% due to independent rounding.

Now that they know how greenhouse gases get into the atmosphere, they can start thinking about how to slow the rate of climate change.

TEACHER NOTES

Source data

- ✓ The information for the local pollution source database comes from the National Emissions Inventory published by the US EPA. The database is updated every three years. These data come from the 2017 version of the database. Learn more about the NEI here: https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei

Cause & effect connection

- ✓ When students are considering how to slow the rate of climate change, consider having them look back at the cause & effect chain they developed in Activity 4 and thinking about ways that they can "break the chain"

TEACHER NOTES

Next steps

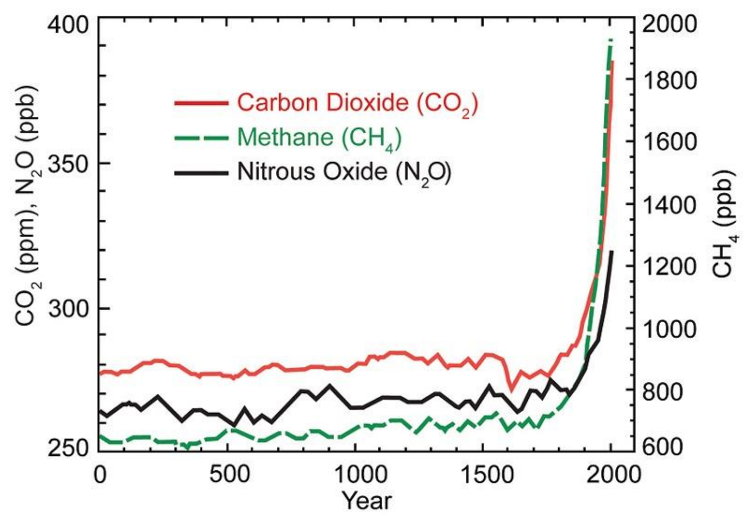
- ✓ The last activity in this module involves students making a plan to reduce their greenhouse gas emissions or build resilience into their community. As soon as you have their brainstorm sheets, begin thinking about how to tie their ideas into this final activity. You might want to type up students lists so it is easier to share it with them during the next activity.

Have students start brainstorming on their handout things that they can do to prevent climate change. Encourage them to be as specific as possible (ex. "Turn of my Xbox when I am done playing" vs. "use less electricity").

Once students have had a chance to make a list on their own, have them share their lists with others in a small group. Give each group a sheet of paper so they can make a list for the whole group with all of their ideas.

When students are done, thank them for thinking about ways to protect the Earth. Then collect the lists and tell students that they will come back to these ideas during their next activity.

8. **Formative assessment:** Display the graph up from the warmup so all students can see it:



Have students write a short explanation of why the graph goes up so much towards the end. Their answer should include what they learned about fossil fuels and how humans use them. Even if students haven't learned about the industrial revolution, they should be able to conclude that this was the time we started burning lots of fossil fuels (and discovered others) to make electricity, and around the time that cars were invented that burned fossil fuels. They may also realize that human population has grown a lot during this time period, which also contributes to the big spike in CO_2 levels in the atmosphere.

Name________________________________

STUDENT NOTES SHEET

Carbon Dioxide and Fossil Fuels

How are fossil fuels connected to climate change?

Living things are made of		and other elements
Millions of years ago, dead		were buried underground
Over time, they were formed into		called fossil fuels, because they are old like fossils
Humans dig these resources out of the ground and		to produce electricity in power plants and power cars and trucks
Burning fossil fuels releases		which causes climate change

Sources of greenhouse gases

1. What do the top 10 sources of greenhouse gases in the area have in common?

   ____

2. Look at the top 30 sources of greenhouse gases. Besides electricity generation, what other kinds of sources are there? ______________________________

3. What are the top three local sources of greenhouse gas emissions and what type of sources are they (ex. electricity generation, institutional, etc.)?

   ____

   ____

   ____

4. What do you notice about the top sources of criteria pollutants compared to the top sources of greenhouse gases?

   ____

5. What does this tell you about the how different kinds of air pollution are related?

   ____

   ____

6. What can <u>you</u> do to keep carbon dioxide out of the atmosphere?
   - ______________________________
   - ______________________________
   - ______________________________
   - ______________________________
   - ______________________________

Activity 10 (Elaborate): Doing Our Part

Activity summary: In this action-oriented activity, students think about individual and group actions they can take to fight climate change. They also engage with stories that show the power that young people have to make a difference in the fight against climate change. Using this information, students create individual pledges and develop a group action project to address climate change in their community.

Standards Connection
DCI: ESS 3.C: Human Impacts on Earth Systems
DCI: ESS 3.D: Global Climate Change
CCC: Cause & Effect

Timing and other thoughts on this activity

Climate change can be disheartening for students, especially if they have routinely been presented with "doom and gloom" scenarios about the future of the planet. Providing an opportunity for them to make small changes for themselves and their communities is an important way to build their sense of empowerment, and to learn to live the "think globally, act locally" philosophy. This activity presents a variety of options that take different amounts of time, resources, and effort to achieve. Choose those that fit within your constraints, and provide students with the opportunities to make a real difference. If the project goes on for multiple days, you may choose to give students the assessment (Activity 11) when students need a break from the project.

Warmup: Display the photo collage below, and ask students what all these things have in common.

ACTIVITY DETAILS

Time: 2 or more class periods

Objectives
- ✓ Students will use what they have learned in the module to create individual and group action plans to address climate change.
- ✓ Students will advocate for climate change in their communities by completing a group action project.

Materials
- ✓ Computer & projector
- ✓ Speakers (for video)
- ✓ Student computers (optional)
- ✓ Make A Pledge!

Handouts
- ✓ My carbon footprint
- ✓ What I Can Do, What We Can Do

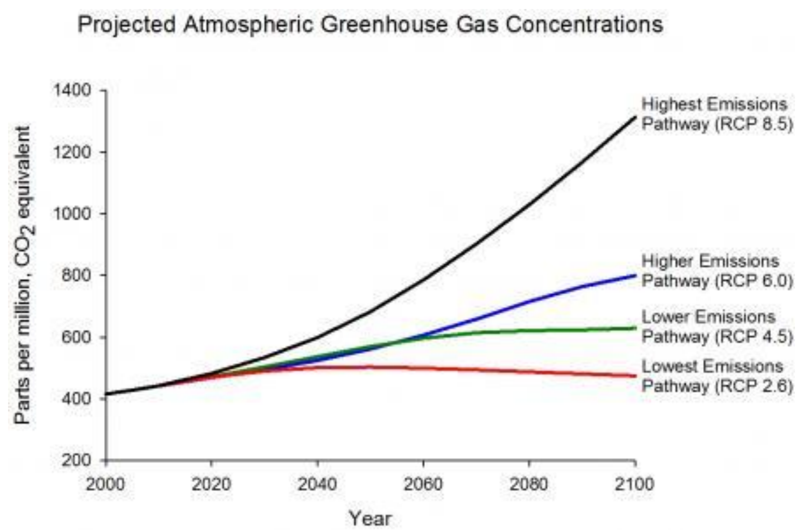
TEACHER NOTES

Teacher Tip

- ✓ The "My Carbon Footprint" sheet is generic and can be used with any of the footprint calculators, although it is closely patterned after the first one on the list. For the others, you may need to help students decide on things they can do to help lower their carbon footprints.

- Each of these pictures represents a way to reduce greenhouse gas emissions to prevent climate change: bicycling (instead of taking a car), turning off the lights when not in use, using energy from solar panels instead of fossil fuels, and eating a plant-based diet.

1. **Frame the activity:** Show students the greenhouse gas concentration graph from Activity 8 and remind them that we as humans can do a lot to prevent climate change. If we change the cause of climate change, we can change the effects. Our goal is to get this greenhouse gas graph to stop going up and start going down. And we all have the power to do our part to make it happen. During the last activity, students brainstormed ways that they can help protect the Earth from climate change. Today they are going to develop ways to put those ideas into action.



2. **Carbon footprints (optional):** Pass out the "My Carbon Footprint" sheet to students. Tell them that a good way to figure out what they can do to prevent climate change is to calculate their carbon footprint. A carbon footprint is the amount of greenhouse gases you put into the atmosphere through your actions (including how much electricity you use) during a whole year. Have students add this definition to their sheets. Share that your carbon footprint is based on where you live, how you get around, what you eat, and how you use electricity.

   If student computers are available, pass them out, and have students complete one of the carbon footprint calculators below. If not, you may choose to do one for the whole class together. There are many different carbon footprint calculators to choose from that take different amounts of time and require different amounts of knowledge. On the next page there are links to a few that are student-friendly:

- https://calc.zerofootprint.net/ (simpler, and includes details on how to decrease your footprint)
- https://ei.lehigh.edu/learners/cc/carboncalc.html (more detailed, but no suggestions for decreasing footprint)
- https://depts.washington.edu/i2sea/iscfc/fpcalc.php?version=ms (very detailed, but no suggestions for decreasing footprint)

3. **What can we do?** Ask students if they feel like they have the power to fight climate change in their communities. Lead them in a short discussion about why they do or don't feel like they have that power. Then share some stories of young people who are working to make a difference in their communities and for the world. Students may have heard of Greta Thunberg. This video about Greta is a great way to help students see the power that they can have: https://www.youtube.com/watch?v=uRgJ-22S_Rs. Students should also have a chance to see other young people who look like them who are fighting for climate change. Consider having students read about one of these other young climate activists who come from a diverse variety of backgrounds: https://www.cnn.com/2019/09/28/world/youth-environment-activists-greta-thunberg-trnd/index.html

   You can also share this episode of the Flossy podcast, which is an award-winning podcast developed by a group of Black high school students in Canarsie, NY.
   - Podcast: https://soundcloud.com/canarsiestudios/climate-change-environmental-racism
   - Their story: https://www.npr.org/2020/06/03/867842394/the-winners-of-the-npr-student-podcast-challenge

   Afterwards, revisit the conversation about whether they have the power to fight climate change in their communities, and see if their opinions have changed.

4. **Make an individual plan:** Hand out the "What I Can Do, What We Can Do" sheet, and read through the top part together. Then share the lists that students brainstormed in the last activity about what they can do to fight climate change, either by giving back their papers, or by sharing a summary of their ideas. There are some additional ideas on the back of their handouts. Have students make an individual commitment for what they want to do at the top of the page based on their lists.

TEACHER NOTES

Climate Change and Equity

✓ Many suggestions for how to lower your carbon footprint are closely related to standards of living and living conditions. For example, riding a bicycle to school may be safe in some neighborhoods but not others. Buying locally-sourced fruits and vegetables depends on having access to these resources. Be mindful of inequities that make some changes difficult for some students. Also consider how you can help students advocate for things like a school-based farmers market that can challenge these inequities.

Modifications

✓ There are many different ways to help students take action. Focus on what students want to do and use what they are passionate about to drive the decision-making.

TEACHER NOTES

Other Resources

- ✓ Project Drawdown has numerous ideas for how to reduce your carbon footprint. Students and schools can also form teams and make pledges online. The Project Drawdown Ecochallenge is a good way to start. It takes some time to learn how to navigate the site, but the resources are well worthwhile. Check it out here: https://drawdown.ecochallenge.org/

Pledge Drive

- ✓ A great way to involve the school community and teach students about advocacy is to hold a pledge drive. Have students take a copy of the Make A Pledge! sheet and go to their families, friends, teachers, and neighbors asking them to pledge to make a change. Students can record pledges on paper cutouts of Earth or other shapes. Make a classroom collage of all the shapes and total up the pledges to celebrate success.

5. **Choose a group project:** Have students think about what they can do as a class to help fight climate change. They may already have some ideas from thinking about their individual action. The back of their sheet has some additional ideas. Discuss with students what they would like to do. Be sure to guide the conversation to keep student ideas within budgetary and time constraints. It will only take a class period to make signs to put up around the school reminding people to turn off the lights, but it might take several days to plan a fundraiser, make a video, or plan a school rally. Help students select a plan that they can be successful with.

   If some students want to do a larger project, consider starting an environmental club that can work on longer-term projects.

6. **Plan the project**: If students are interested in taking on a project that requires additional planning, have them divide the project up into smaller pieces that groups of students can work on. For a school rally, some students may make posters, while others write a letter for school staff, administration, or parents. You will likely need to do some planning outside of class, but try to include students in planning as much as possible. Once you have a plan developed, make sure to share that plan with students.

7. **Implement the plan**: Follow your plan, and make adjustments along the way as necessary. Be sure to document your students' work along the way with pictures, videos, etc.

8. **Celebrate success**: When the project is complete, take time to reflect on and celebrate what you and your students have accomplished. How much carbon dioxide will stay out of the air if people keep their pledges? Did you hold a rally or present at a school assembly? Write a story about it for the local newspaper or the school website. Share your success with others in the environmental conservation community.

Name________________________________

STUDENT DATA SHEET

My Carbon Footprint

What is a carbon footprint? ____

____

What is your carbon footprint?____________________tons/kgs of carbon dioxide.

How does your carbon footprint compare with the United States average? (18 tons or 7,800kg) ____

____

____

How does your carbon footprint compare with the world average? (5 tons or 3,800 kg) ________

____

____

What kinds of things make your carbon footprint higher?

- ____
- ____
- ____

To get the carbon dioxide concentration back down to a safer level, we need to get each person's carbon footprint down to 3 tons.

What are 3 things you can do to lower your carbon footprint?

- ____
- ____
- ____

Name________________________________

STUDENT GUIDE

What I Can Do, What We Can Do

There are many different ways that young people can help prevent climate change. You have already taken the first step by learning what climate change is. Use this guide to help you think about ways to work with others to increase your influence. Be a leader! Help your community fight climate change!

What I plan to do to fight climate change:
What we as a class plan to do to fight climate change:

Individual Action Ideas

Participate in a climate change rally	Go grocery shopping with your family and look for locally produced foods, especially fresh fruits and vegetables.	Teach a family member or friend about climate change and help them make a change to lower their carbon footprint
Ride your bike to school or to a friend's house instead of riding in a car.	Eat more plant-based foods and less meat and dairy products.	Create a transportation log that shows how many miles you ride in a car in a month. Pledge to reduce the number next month.

Group Action Ideas

Ask your school leaders to make a change that will reduce the school's carbon footprint. For example, serving more vegetarian food at lunch and turning off buses when they pick up and drop off students.	Run a pledge drive! Ask your friends, family members, neighbors and teachers to pledge to do one thing to reduce their carbon footprint. Keep track of how much CO_2 is reduced by people's pledges.	Make a video to educate others about climate change, then share your video with the community.
Advocate for a bicycle rack at school, or a place to store bikes insides so more students can bike to school.	Organize a climate change rally or assembly for your school or community.	Start a club that meets to talk about climate change and work to reduce the school's carbon footprint. If your school is in Maryland, you can work to make your school a Green School.
Advocate to hold a farmers' market at the school once a week or once a month.	Hold a fundraiser to buy Kill A Watt electricity use monitors for the school, then use them to monitor and lower electricity use	Create signs around the school reminding teachers and students to shut off lights and electronics when they're not being used

Make a Pledge!

Action	Approximate Pounds of CO_2 saved
Take a day (or more!) off from eating meat and dairy products	8 pounds for every day off
Ride a bicycle or walk next time you need to go somewhere nearby instead of driving (or riding) in a car	1 pound for every mile you don't drive
Adjust your thermostat up by 2° in the summer and down by 2° in the winter	5 pounds for every day you use less energy for heating and cooling
Change one light bulb from an incandescent light to a compact fluorescent light	2 pounds for every week with the new bulb
Shorten your shower by 2 minutes	1 pound per shower your take
Recycle cans and bottles	1 pound for every pound of waste you recycle (instead of putting in the trash)
Recycle newspapers and magazines	3 pounds for every week you recycle
Air dry your laundry instead of using a dryer	3 pounds for every load of laundry
Wash your clothes in cold water instead of hot	1 pound for every load of laundry

Sources: https://www.clackamas.us/sustainability/tips.html, https://www3.epa.gov/carbon-footprint-calculator/

Activity 11 (Evaluate): Earth in 2050

ACTIVITY DETAILS

Time: 30 minutes

Objectives

- ✓ Students will demonstrate their understanding of key climate change ideas related to greenhouse gases, sea level rise, and climate resilience.
- ✓ Students will interpret graphs to draw conclusions about climate change scenarios

Materials

- ✓ Computer & projector

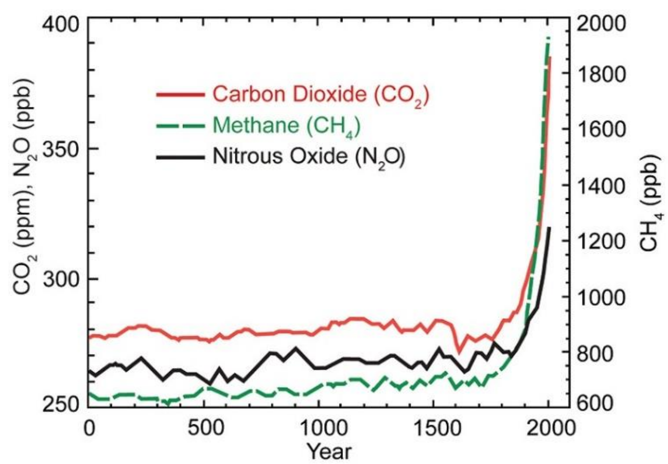
Handouts

- ✓ Earth in 2050 assessment

Activity summary: This summative assessment is designed to evaluate students' understanding of the big ideas of the module by posing a fictional scenario about the future and having students interpret the effects to determine the causes. Students also share what they learned about climate resilience to provide suggestions to a community in need.

Standards Connection
DCI: ESS 3.D: Global Climate Change
DCI: ESS 3.C: Human Impacts on Earth Systems
SEP: Analyzing Data
CCC: Cause & Effect

Warmup: Consider what topic students might need some additional support with before the assessment, and use it to help provide some additional guidance (without giving away any of the answers on the assessment). For example, have students determine approximately what year carbon dioxide levels were at 300 ppm using the graph below (it was just after 1900).



1. **Frame the activity:** Remind students of how much they have learned during the module, and how many questions from Activity 1 they have answered based on their original phenomenon. Assure them that they are prepared to show what they know.

2. **Provide the assessment.** Give students the assessment (Earth in 2050).

3. **Next steps:** After the assessment, consider if there are any questions left from Activity 1 that you want to address, and finish any action projects that are still ongoing. Be sure to give students feedback on their assessment, and celebrate all that they have learned!

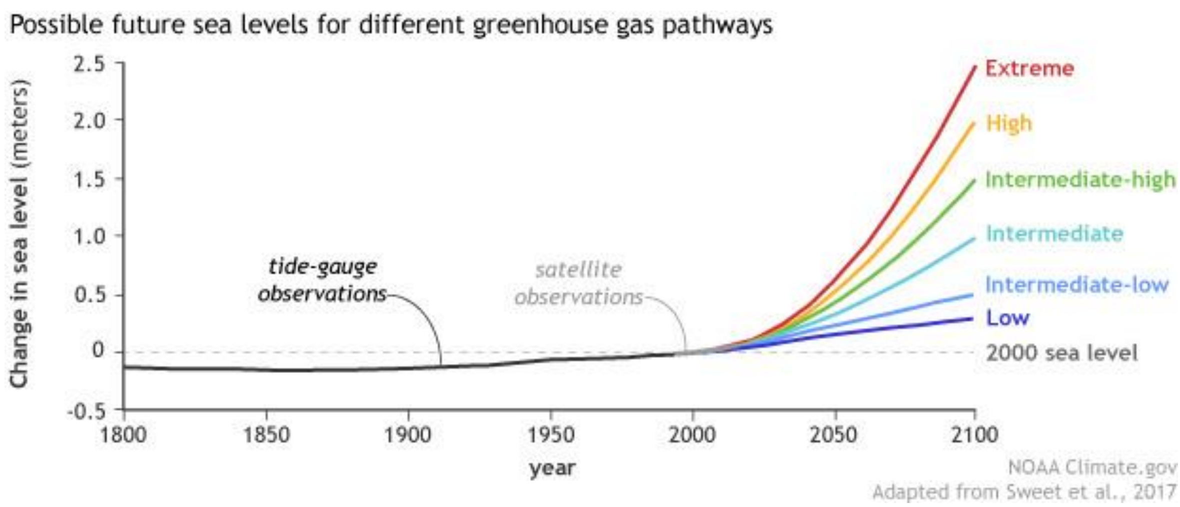
Name ______________________

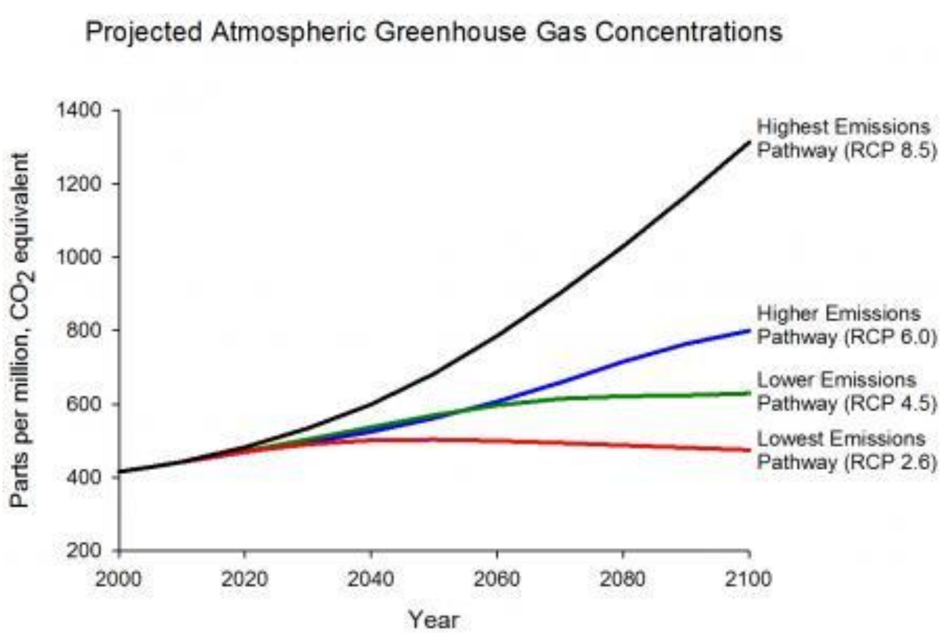
STUDENT ASSESSMENT

Earth in 2050

Imagine that it is the year 2050. You are a professional climate scientist who specializes in studying sea level rise. You have been collecting and analyzing data on how much the ocean has risen since 2000. According to your measurements, the sea level has risen by 0.2 meters since 2000 (8 inches). You would like to use this information to think about how the Earth has changed in the last 50 years, and what humans have been doing to prevent climate change.

Use this information and the graphs below to answer the questions on the following pages.





1. Based on the amount of sea-level rise, what pathway (scenario) for sea level rise do you think happened (extreme, high, intermediate, or low)?

   ____

   How did you find your answer? ______________________________

   ____

   ____

2. Based on the pathway you think happened, what do you think the concentration of greenhouse gases in the atmosphere is in 2050?

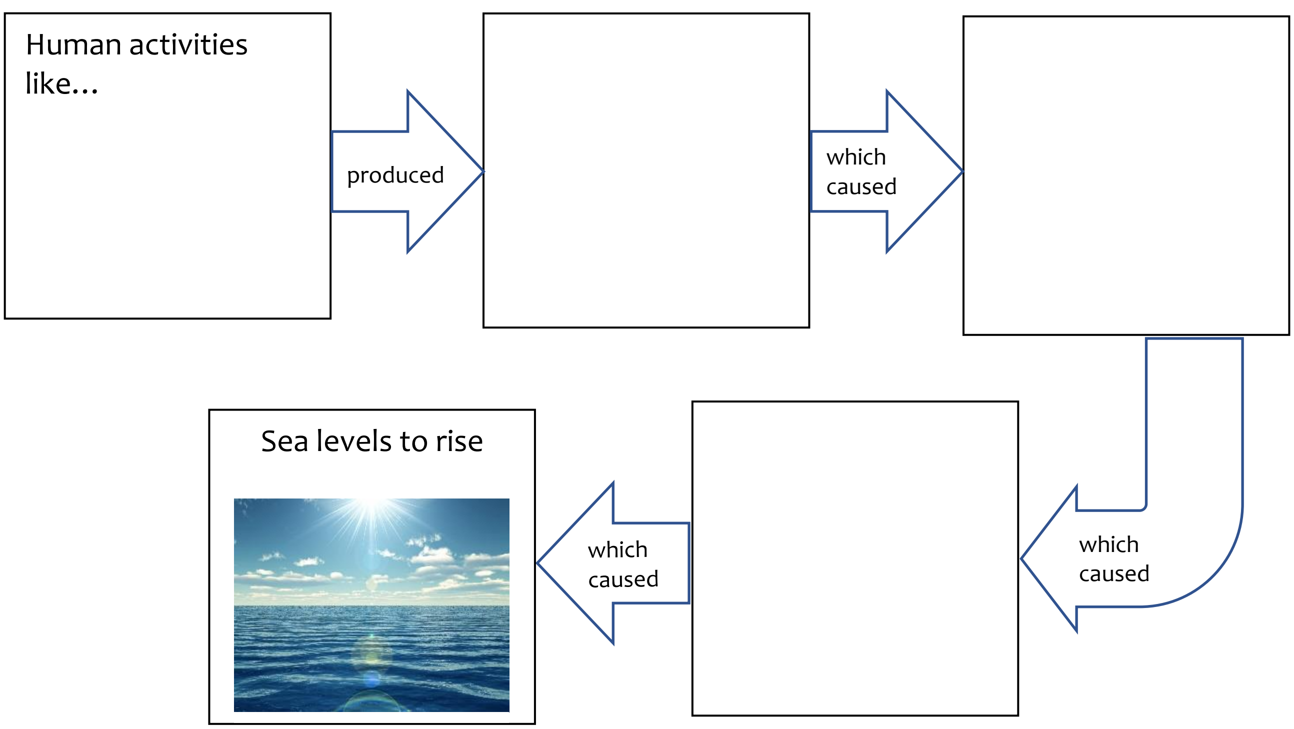
   ____

   How did you find your answer? ______________________________

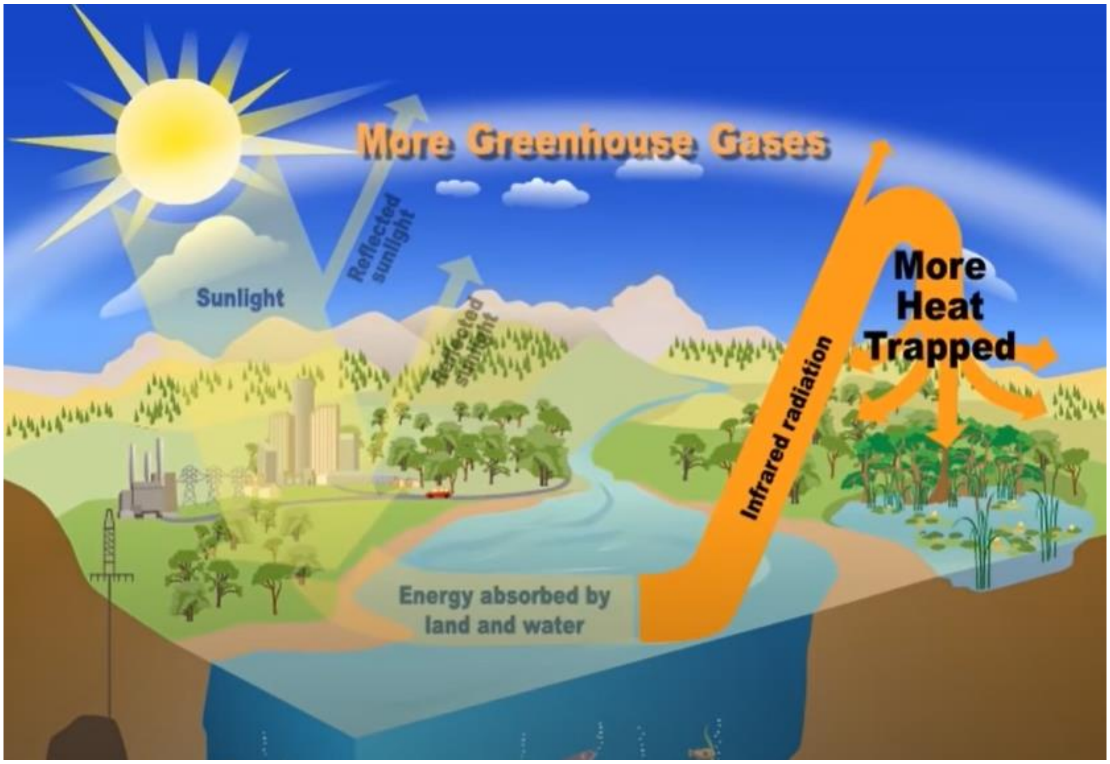
   ____

   ____

3. Sea level rise is an effect that has many causes. Fill in the boxes in the cause-effect chain below to show how human activities have led to rising sea levels.



4. The greenhouse effect is closely related to climate change. Use the diagram below to write an explanation of how the greenhouse effect works:



5. What are humans doing that increases the greenhouse effect?

6. Based on the pathway (scenario) that humans followed, what kinds of things do you think humans did to prevent climate change? Include <u>at least three things</u> in your answer.

____

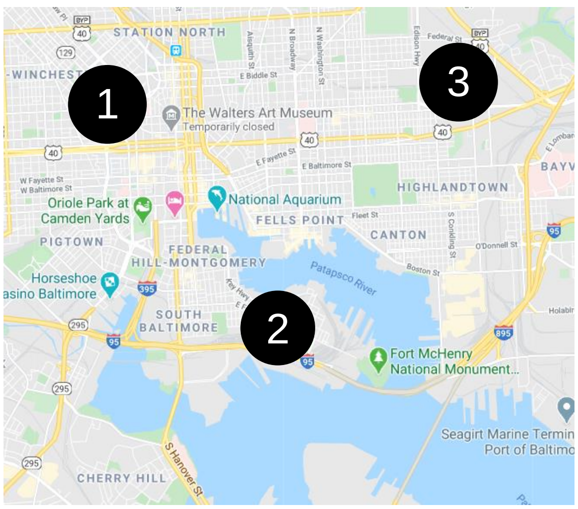
____

____

____

____

7. The Baltimore city government calls you to ask if they should be worried about rising sea levels. Look at the map below that shows a section of Baltimore.



Which neighborhood is most at risk for rising sea levels? (1, 2, or 3)?

____

Why are they most at risk? ____________________

____

____

____

8. The community you identified calls you to ask what they can do to make their neighborhood more <u>resilient</u> to rising sea levels. What suggestions would you make to them? Include <u>at least two suggestions</u> in your answer.

____

____

____

____

____

____

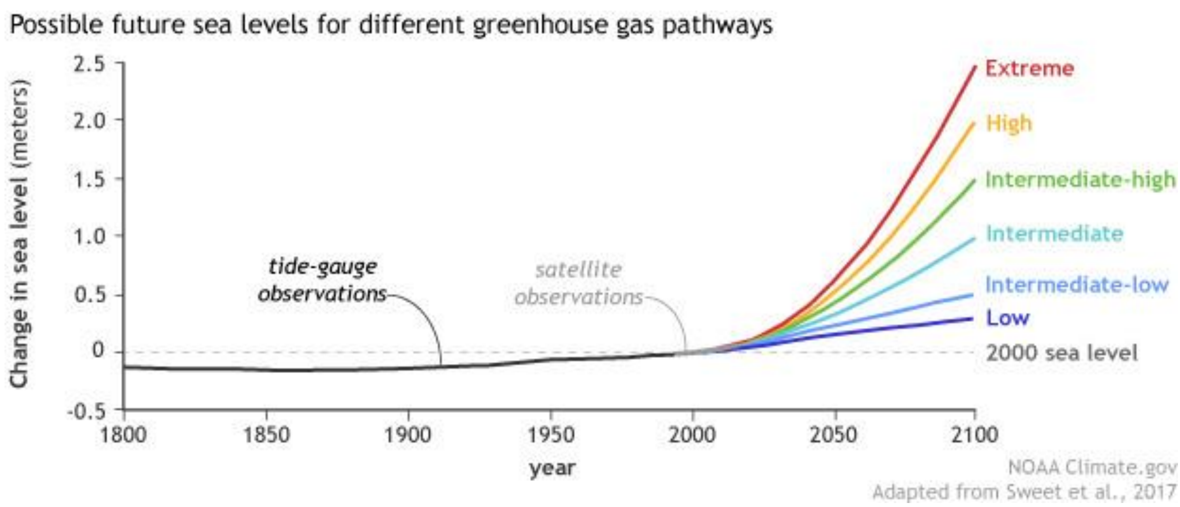
ANSWER GUIDE

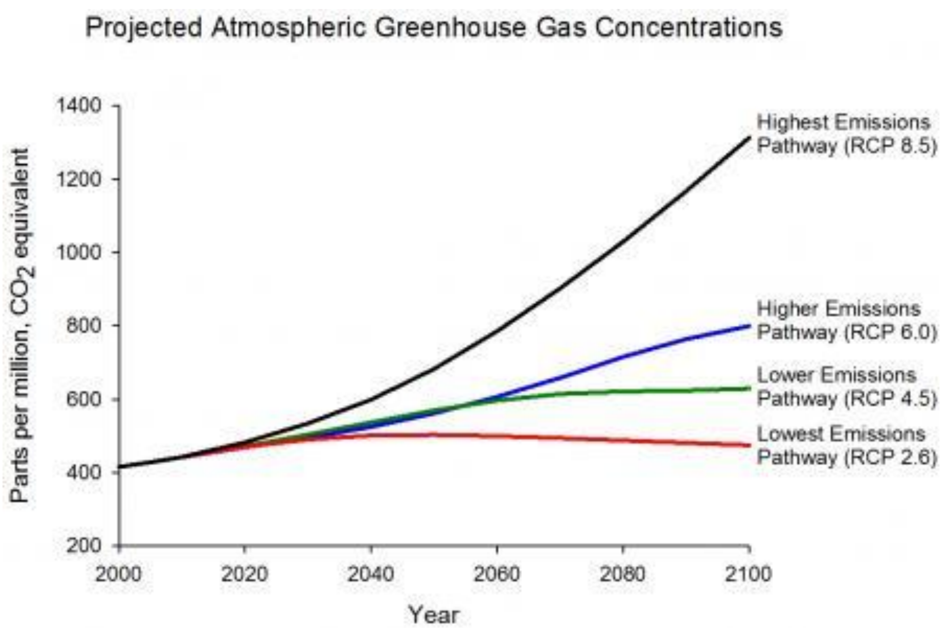
Name ______________________________

Earth in 2050

Imagine that it is the year 2050. You are a professional climate scientist who specializes in studying sea level rise. You have been collecting and analyzing data on how much the ocean has risen since 2000. According to your measurements, the sea level has risen by 0.2 meters since 2000 (8 inches). You would like to use this information to think about how the Earth has changed in the last 50 years, and what humans have been doing to prevent climate change.

Use this information and the graphs below to answer the questions on the following pages.





1. Based on the amount of sea-level rise, what pathway (scenario) for sea level rise do you think happened (extreme, high, intermediate, or low)?

   Low

   How did you find your answer? I looked at the first graph and found the sea level rise for 0.2 meters on the y-axis. I went across to 2050, and saw that it intersected with the graph for the low pathway

2. Based on the pathway you think happened, what do you think the concentration of greenhouse gases in the atmosphere is in 2050?

   500 ppm

   How did you find your answer? I looked the bottom graph, and found where 2050 was on the x-axis. I went up to the lowest emissions scenario and then across to the y-axis. It was about in the middle of 400 and 600ppm, so I estimated it was 500 ppm.

3. Sea level rise is an effect that has many causes. Fill in the boxes in the cause-effect chain below to show how human activities have led to rising sea levels.

Human activities like…

Burning fossil fuels to make energy
Driving gas-powered cars

produced

Greenhouse gases like carbon dioxide

which caused

Global temperatures to rise (increased the greenhouse effect)

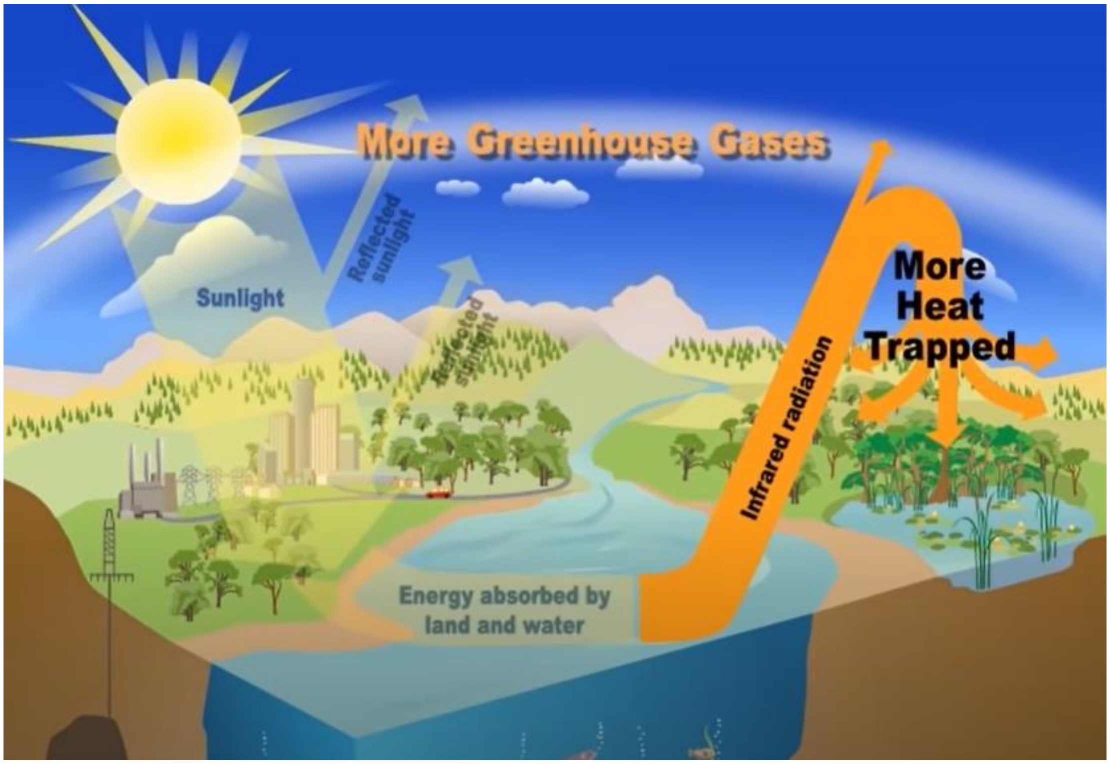
which caused

Land ice to melt (and thermal expansion of ocean water)

which caused

Sea levels to rise

4. The greenhouse effect is closely related to climate change. Use the diagram below to write an explanation of how the greenhouse effect works:



Sunlight from the sun heats up the Earth (land and water). The Earth then sends some of that heat back out into the air. Some of the heat goes back out into space, but some of it is trapped by greenhouse gases, which keeps the Earth warm.

5. What are humans doing that increases the greenhouse effect? Humans produce more greenhouse gases when they burn fossil fuels for energy or transportation. This increases the greenhouse effect.

6. Based on the pathway (scenario) that humans followed, what kinds of things do you think humans did to prevent climate change? Include <u>at least three things</u> in your answer.

   Used more clean transportation (electric vehicles, mass transit, bicycles)

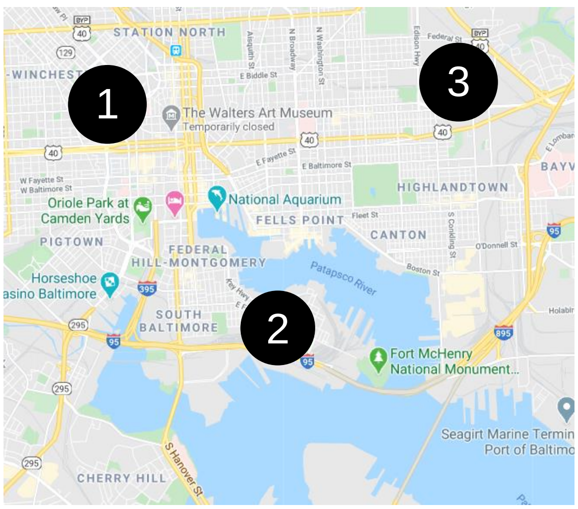
   Ate more locally-produced food and less meat

   Used energy more efficiently (turned off lights, electronics, etc.)

   Used more clean energy sources (wind, solar, geothermal, tidal)

   Many other answers possible

7. The Baltimore city government calls you to ask if they should be worried about rising sea levels. Look at the map below that shows a section of Baltimore.



Which neighborhood is most at risk for rising sea levels? (1, 2, or 3)?

2

Why are they most at risk?

It is closest to the water, and likely the lowest in elevation.

8. The community you identified calls you to ask what they can do to make their neighborhood more <u>resilient</u> to rising sea levels. What suggestions would you make to them? Include <u>at least two suggestions</u> in your answer.

   build walls at the water's edge to prevent flooding

   create low-lying grassy areas with plants that will help to absorb floodwaters

   create channels to direct flood water back to the harbor

   build new buildings that have a ground floor that is above ground level)

   other creative answers are possible

Air Quality Champion in Our Community

Name: Vernon Morris
Titles: Director of the Cooperative Science Center in Atmospheric Science & Meteorology (NOAA); Professor of Chemistry & Atmospheric Sciences (Howard University)
Organization: National Oceanic & Atmospheric Administration (NOAA)

How does your work relate to air quality?
At NOAA, I lead teams of scientists, university students, and professors to work on problems of air chemistry, weather, and climate. We work on projects to improve predictions about air pollution, develop new ways to measure chemicals in the environment, and study how climate change and air quality affect each other. As a professor, I teach, develop new courses, and support education and career opportunities in environmental science, particularly for students from disadvantaged backgrounds.

What motivates you to come to work every day?

- ✓ Curiosity. I love learning and finding out how and why things in nature work the way they do. My job allows me to uncover the mysteries of the Earth's environment.

- ✓ The possibility of making a difference. Whether I'm providing educational tools and programs or conducting research that will lead to a better quality of life for people all over the world, I feel like the work that I do makes a difference. Sometimes, I even get to see the fruits of my labor when a student becomes a successful professional or my research leads to policy or process changes in an organization or society.

- ✓ Engagement with students. I absolutely love to be around people who want to learn new things. I am fortunate to have a job that continually seeks and shares knowledge. Being around people who love learning is energizing.

What education and career path did you pursue to have the position that you have today?
Growing up, I thought that I would enter the military and travel the world. In high school, I envisioned myself becoming a professional fighter. A dramatic event changed my mind and I literally stumbled into my current career. Shortly after entering Morehouse College, I found myself unable to pay some of my tuition. I was dashing through the chemistry building on my way to find a job and ran smack into a chemistry professor. This professor not only paid my tuition, he found me a part-time campus job and convinced me to major in Chemistry and Mathematics. I went on to become the first African American to earn a PhD in Geophysical Sciences (now Earth and Atmospheric Sciences) at Georgia Tech. After that, I began my research in a mountain monastery in Sicily and have now conducted research on five of the seven continents, three of the five major Oceans, and visited over 30 countries.

What is your workspace like?
On a typical day, I may be in a meeting room in the morning, a classroom in the afternoon, and a rooftop lab after that. My favorite workspace is aboard research ships that sail out into the remote oceans to conduct experiments. On the ships, I launch balloons that carry delicate instruments up in the atmosphere to measure the properties of the air. I also monitor air chemistry on deck, and even send devices into the sea to measure gases.

What accomplishment are you most proud of?
My proudest accomplishment has been my children. I have three intelligent and beautiful daughters and a son on the way. A close second is enabling the success of the 150 students whom I have mentored over the years. Many of these students have gone on to become successful doctors, scientists, engineers, and business owners. I take a lot of pride in opening doors and enabling people to achieve their dreams.

Is there something important that you want to share that we haven't asked?
A little advice: believing in yourself is important but not enough. Hard work is essential but not enough. Combining these two elements and building meaningful professional relationships will take you a long, long way towards achieving your dreams. You have to find people who will fight for you and help open doors for you. You have to be prepared to do your job well when the door is opened. And once you get through the door, make sure that you reach back and help someone else.

Glossary

carbon dioxide (CO_2) – a colorless, odorless gas produced by burning carbon and organic compounds such as fossil fuels, and by cellular respiration. It is naturally present in air (about 0.03 percent) and is absorbed by plants in photosynthesis. Carbon dioxide is also a major greenhouse gas.

carbon footprint – the amount of carbon dioxide and other carbon compounds emitted due to the consumption of fossil fuels by a particular person, group, etc.

causation – a change in one variable directly resulting in the change of another variable through a direct mechanism

climate – the weather conditions in a given area over a long period of time, ex. temperature and rainfall

climate change – any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among other effects, that occur over several decades or longer.

climate resilience – the ability to anticipate, prepare for, and respond to hazardous events, trends, or disturbances related to climate.

community climate resilience - the ability of communities to prepare for, respond to, and recover from hazardous events and adversity related to climate change

control – a variable which is kept constant across groups in a controlled experiment in order to isolate the effects of the other variables

correlation – a mutual relationship or connection between two or more things. Often shown as a relationship between two variables or quantities in a graph or chart

dependent variable – a variable that is measured by the experimenter in a controlled experiment, and whose value depends upon the independent variable

fossil fuel – a natural fuel such as coal or gas, formed in the geological past from the remains of living organisms.

global warming – recent and ongoing rise in global average temperature near Earth's surface. It is caused mostly by increasing concentrations of greenhouse gases in the atmosphere.

greenhouse effect – the trapping of the sun's warmth in a planet's lower atmosphere by particular gases

greenhouse gas - a gas that contributes to the greenhouse effect by absorbing infrared radiation (heat), e.g., carbon dioxide and chlorofluorocarbons

independent variable – a variable that is changed by the experimenter in a controlled experiment

land ice – frozen water that is on land, including mountain glaciers and **ice** sheets covering Greenland and Antarctica

parts-per-billion (abbreviation ppb) – a unit of measure equal to 1 in 1 billion, or 0.0000001%. 1 ppb is also equivalent to 1 μg/liter.

parts-per-million (abbreviation ppm) – a unit of measure equal to 1 in 1 million, or 0.0001%. 1 ppm is also equivalent to 1 mg/liter.

RCP (Representative Concentration Pathway) – is a greenhouse gas concentration (not emissions) trajectory. The pathways describe different climate futures, all of which are considered possible depending on the volume of greenhouse gases (GHG) emitted in the years to come

sea ice – frozen, floating ocean water

sunny day flooding – temporary flooding of low-lying areas, especially streets, during exceptionally high tide events, such as at full and new moons. Also known as nuisance flooding or tidal flooding.

tide – the alternate rising and falling of the sea, usually twice in each lunar day at a particular place, due to the attraction of the moon and sun.

urban heat island – a phenomenon wherein an urban area or metropolitan area is significantly warmer than its surrounding rural areas due to human activities.

weather – the state of the atmosphere at a given place and time in terms of temperature, humidity, precipitation, wind, etc.