American Museum of Natural History

CLIMATE CHANGE

The Threat to Life and A New Energy Future

EDUCATOR'S GUIDE

amnh.org/education/climatechange

INSIDE:

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- **Essential Questions** for Student Inquiry
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essential QUESTIONS

This exhibition explores how climate works, why it is warming, what the consequences might be, and how to address them. Use the Essential Questions below to connect the exhibition's themes to your curriculum.

What is climate?

Climate is the long-term state of weather: the typical weather in a particular region over years. The Sun drives climate by warming the air, land, and sea. The oceans and atmosphere transport this heat from the tropics to the poles. In the short run, this transfer of energy creates weather (like a tornado or a sunny day); over the long run it creates climate (warm near the Equator, for example, or cold near the poles). The distribution of landmasses, the amount of ice cover, and the presence of life also play important roles in Earth's climate system.

How does climate change?

In the past, temperatures at Earth's surface have risen and fallen naturally. Glacial periods alternated with shorter, warmer interglacial periods like the one we're in right now. However, temperatures remained within a range that has enabled life to survive and evolve for more than 3 billion years. That's because gases in the atmosphere, known as greenhouse gases, absorb heat emitted by Earth. Without this insulating blanket, the surface of Earth would actually be frozen. When the concentration of greenhouse gases in the atmosphere increases, more heat is trapped and Earth warms. Carbon dioxide (CO_2) is the most significant of the greenhouse gases. Others include water vapor, methane, and nitrous oxide.

How are people causing Earth's climate to change?

Over the last 100 years, human activity is causing global average temperatures to rise. In particular, the burning of fossil fuels (coal, oil, and natural gas) is releasing carbon that had been locked within Earth's geologic reservoir for millions of years. The burning of coal to generate electricity is the most significant source of this CO_2. Deforestation also plays a part: trees remove CO_2 from the atmosphere through photosynthesis, and when trees burn, the carbon inside them rapidly turns into CO_2. Since the Industrial Revolution at the end of the 18th century, concentrations of this greenhouse gas have grown faster and higher than at any time in the past 850,000 years (and probably much longer).

How do we study global climate?

Climate is enormously complex, and scientists have yet to understand how the system operates as a whole. Observations of present-day temperatures and greenhouse gas concentrations made by thermometers, ocean buoys, and satellites are key. Scientists also study the geologic record—information preserved in tree rings, fossil corals, glacial deposits, deep-sea sediments, and glacial ice—to understand how climate has changed in the past. Computer models based on all these observations help them understand what the future may hold.

How does climate change affect our world?

All living things, from penguins to palm trees, survive only within a particular set of environmental conditions. Even a small change can upset the delicate balance in which species coexist. For example, changing ocean chemistry may kill the coral animals that create tropical reefs. These disturbances ripple through the web that connects all living things, threatening Earth's biodiversity in countless ways. The increase in average global temperatures may also intensify extreme weather events such as droughts and severe storms.

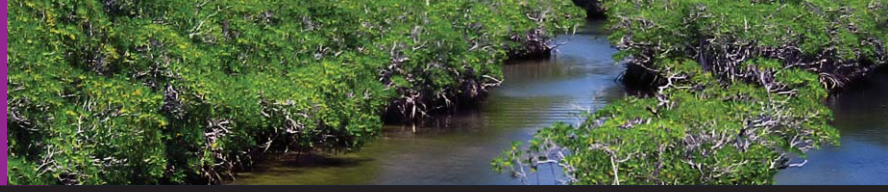
Warmer ocean waters could make storms more powerful.

How could climate change affect human society?

While we can use technology to modify our surroundings, humans are not immune to the effects of climate change. Society could be at serious risk. For example, droughts could disrupt agriculture, causing starvation. Storm surges and rising sea levels could displace the hundreds of millions of people who live on or near seacoasts. Changes in temperatures and the distribution of rainfall could lead to disease outbreaks. The kind of social and economic upheaval that disrupts societies could result. We don't know what's going to happen, but we do have the power to act.

What can we do to address climate change?

The decisions we make affect Earth's climate. These decisions are made at all levels: by individuals, communities, and countries. As individuals, we can use less energy in our homes, schools, and workplaces; recycle and reuse; buy locally grown produce; build energy-efficient "green" buildings; drive less; and reduce our energy use in countless other ways. On a broader scale, governments can encourage the development of non-fossil fuel-based energy sources like solar, wind, and nuclear power; investigate strategies to remove CO_2 from the atmosphere; and support sustainable development. While there is no single way to address climate change, people and communities acting together can reduce CO_2 emissions. Not acting is the riskiest course of all.



Useful Terms & Concepts

adaptation: the adjustment of living things to environmental conditions. Human adaptation to climate change includes altering the way we grow crops, build homes, consume energy, and manage natural resources.

carbon cycle: the constant movement of carbon through living things, rocks, the oceans, and the atmosphere

carbon dioxide (CO_2): a colorless, odorless gas that is naturally present in the atmosphere

climate: the average long-term weather (commonly years) in a particular region

climate models: computer programs that enable scientists to investigate the many factors at work in Earth's climate system. By manipulating variables such as the amount of CO_2 in the atmosphere, scientists try to understand how the climate will respond.

fossil fuels: coal, oil, and natural gas, which formed from the remains of organisms that lived millions of years ago

global warming: an increase in the average temperature at Earth's surface caused by the buildup of greenhouse gases in the atmosphere

greenhouse effect: the process by which an atmosphere warms a planet. This takes place when gases allow sunshine to pass through the atmosphere but absorb the heat that radiates back from the surface, keeping it warm.

greenhouse gases: gases that increase global temperatures by absorbing the radiation emitted by Earth's surface. Carbon dioxide is the most important greenhouse gas as far as climate change is concerned. Other greenhouse gases include water vapor, methane, and nitrous oxide.

methane (CH_4): a colorless, odorless, flammable gas produced by a variety of natural sources, including microorganisms, cattle, and termites

nitrous oxide (N_2O): a colorless gas or liquid produced by the combustion of fossil fuel

paleoclimate: the past climate, before humans started measuring and recording it

parts per million (ppm): units used to measure concentrations of trace gases. Values refer to the number of specified molecules contained in 1 million molecules of dry air.

permafrost: the permanently frozen layer of soil beneath the surface in cold regions

photosynthesis: the process by which green plants use sunlight to synthesize food from CO_2 and water. Photosynthesis releases oxygen into the atmosphere.

respiration: the process within living cells that releases CO_2 and water when organic compounds combine with oxygen and break down

water cycle: the cycling of water among oceans and lakes, land, living organisms, and the atmosphere

water vapor: the gaseous state of water

weather: the state of the atmosphere at a particular place and time

Come Prepared

Before your visit, review the **Essential Questions** to see how the exhibition's educational themes connect to your curriculum. Identify what you'd like your students to learn from *Climate Change*, and how they could continue learning back in the classroom.

There are many ways to explore the *Climate Change* exhibition:

- You (and your class chaperones) can use the **Teaching in the Exhibition** section of this guide as you move through the gallery with students.
- You can create student worksheets using the **Teaching in the Exhibition** section.
- Students can use copies of the enclosed **Student Worksheets** as they explore the exhibition independently.
- You can distribute copies of the **Map of the Exhibition** to chaperones and/or students, and let them choose their own paths.

After you leave *Climate Change*, or the next time you visit, you and your students can explore the exhibition's themes elsewhere in the Museum. Refer to the inserts: **Connections to Other Museum Halls** and **Explore the Gottesman Hall of Planet Earth**.

Visit amnh.org/education/climatechange for:

- information on field trips, reservations, lunchrooms, and other useful tips to help plan your visit
- free resources, including activities and references
- a link to the *Climate Change* exhibition website

Correlation to Standards

Your visit to the *Climate Change* exhibition can be correlated to the standards listed below. Visit **amnh.org/resources/rfl/web/climatechangeguide/standards.html** for a full listing of relevant NYS Science Core Curriculum Standards and NYC Scope & Sequence.

National Science Education Standards

All grades • A1: Abilities necessary to do scientific inquiry • A2: Understanding about scientific inquiry • E1: Abilities of technological design • E2: Understanding about science and technology • G1: Science as human endeavor

K–4 • C1: The characteristics of organisms • C3: Organisms and environments • D1: Properties of Earth materials • D3: Changes in Earth and sky • F3: Types of resources • F4: Changes in environments • F5: Science and technology in local challenges

5–8 • C1: Structure and function in living systems • C3: Regulation and behavior • C4: Populations and ecosystems • C5: Diversity and adaptations of organisms • D1: Structure of the Earth system • D2: Earth's history • F2: Populations, resources, and environments • F3: Natural hazards • F4: Risks and benefits • F5: Science and technology in society • G3: History of science

9–12 • C4: Interdependence of organisms • C5: Behavior of organisms • D1: Energy in the Earth system • D2: Geochemical cycles • D3: Origin and evolution of the Earth system • F2: Population growth • F3: Natural resources • F4: Environmental quality • F5: Natural and human-induced hazards • F5: Science and technology in local, national, and global challenges • G3: Historical perspectives

TEACHING in the exhibition

The *Climate Change* exhibition uses interactives, models, videos, and more to engage all learning styles. The eight areas below are labeled on the Map of the Exhibition.

1. Introduction

OVERVIEW: This area charts the dramatic rise of atmospheric carbon dioxide (CO_2) over the past 400 years and its link with industrial activity and population growth.

EXPLORATION:

- **"400 Years of CO_2" graph:** Invite students to make connections between technology, energy use, world population, the size of the world economy, and the rise in Earth's atmospheric CO_2 levels since the year 1600.
- **Coal basket, steam engine, light bulb, and computer:** Students can explore these objects to infer how technological innovations have changed our way of life. Have students focus on the steam engine, which launched the Industrial Revolution.

GUIDING QUESTIONS:

- Why is atmospheric CO_2 on the rise?
- How are different kinds of machines powered?
- How have different kinds of carbon-based technologies affected human societies?

2. Climate Change Today

OVERVIEW: This area explains how the burning of fossil fuels to generate energy releases CO_2 into the atmosphere, and that this is causing Earth's climate to warm.

EXPLORATION:

- **"Greenhouse Effect" wall:** Invite students to investigate how greenhouse gases keep our planet livable.
- **Model of a metric ton of coal:** Students can explore the connection between energy use (electricity), the burning of coal, and CO_2 emissions.

GUIDING QUESTIONS:

- How do greenhouse gases affect Earth's atmosphere?
- What human activities are causing the atmosphere to warm?

Oil—when refined into gasoline and diesel fuel—powers nearly all of the world's cars and trucks.

3. Making a Difference

OVERVIEW: Conserving energy is essential, and there are many ways for individuals to go about it. This area describes changes that can make a difference—if many act.

EXPLORATION:

- **"What Can You Do?" wall:** Invite students to explore all the different ways in which individuals can save energy and consume less—at home, at school, and at work.
- **"Solutions" digital interactive:** Students can envision the multiplier effect of an individual action when thousands or millions of people join in.
- **"The Built Environment" wall:** Students can explore the energy-efficient components of a building or community.
- **"Everyday Actions" wall:** Have students examine how energy conservation and efficiency can help reduce CO_2 emissions. Help them understand that individual actions are only one part of the solution.

GUIDING QUESTIONS:

- What can you do to conserve energy and reduce CO_2 in the atmosphere?
- How could you and others work together to broaden the effect of your actions?

4. Changing Atmosphere

OVERVIEW: This area explains how scientists know that Earth's atmosphere is changing, and some of the expected effects.

EXPLORATION:

- **"Weather vs. Climate" wall:** Ask students to distinguish between weather and climate through photos and a Q&A.
- **Weather journals & thermometer:** Students can explore the tools that scientists use to observe climate and weather.
- **"Air Temperatures Are Rising" graph & ice core sample:** Students can examine the evidence for rising air temperatures and levels of CO_2 emissions.
- **"Uneven Heating" hands-on interactive:** Invite students to find out why Earth is warmer at the Equator than at the poles.
- **"How Climate Works: Atmosphere" globe:** Students can choose animations about the role of clouds and storms.

GUIDING QUESTIONS:

- What's the difference between weather and climate?
- What are some ways in which climate change affects weather?
- What's the evidence that Earth's atmosphere is changing?
- What are some of the consequences of a warming atmosphere?

5. Changing Ice

OVERVIEW: Ice is melting at the poles, and glaciers are shrinking. This area describes the present and possible future impact upon the world around us.

EXPLORATION:

- **"Flooded City" model:** Students can observe the effect of rising sea level on Manhattan.
- **Brain coral:** Invite students to examine a marine fossil, found well above sea level, as evidence of past climate change.
- **"How Climate Works: Ice" globe:** Students can choose animations about sea ice and snow cover across the seasons.
- **Polar bear diorama:** Students can explore how life in the Arctic is being disrupted.
- **"Bouncing Back" hands-on interactive:** Invite students to learn about the albedo effect.

The shrinking Arctic ice cap is forcing some polar bears to forage for food near human settlements.

GUIDING QUESTIONS:

- How will melting ice affect our world?
- What role do seasonal changes in snow and ice cover play in Earth's climate?
- Why is the Arctic so sensitive to climate change?

6. Changing Ocean

OVERVIEW: The ocean plays a vital role in climate by storing heat and carbon. This area explains the effects of higher CO_2 levels and warming temperatures on marine systems.

EXPLORATION:

- **"How Climate Works: Ocean" globe:** Students can choose animations showing the ocean's role in the climate system.
- **Buoy & ocean glider:** Students can examine the tools that climate scientists use to collect data in the ocean.
- **Sediment core sample:** Have students consider what geological evidence of past climate suggests about future changes.
- **"Tiny Ocean Organisms Have a Big Impact" display:** Students can explore how microorganisms affect the ocean's carbon uptake.

GUIDING QUESTIONS:

- How do scientists study ocean temperature and chemistry?
- Why is the ocean so important to Earth's climate?
- How might changing conditions affect marine ecosystems?

7. Changing Land

OVERVIEW: This area explores the effect of climate change on land. Droughts and floods may become more common, with consequences for ecosystems and human society.

EXPLORATION:

- **"How Climate Works: Land" globe:** Students can choose animations about how climatic variations affect land conditions.
- **"Ecosystems & Climate Change" dioramas:** Students can investigate the many ways in which the warming climate may affect biodiversity.
- **Tree ring samples & hands-on interactive:** Invite students to move a magnifier to explore the evidence of past climate changes recorded in tree rings.

GUIDING QUESTIONS:

- Why will both droughts and floods become more common?
- What are some of the ways that climate change is affecting organisms?

8. A New Energy Future

OVERVIEW: This area describes options for meeting the world's increasing demand for energy while reducing CO_2 emissions.

EXPLORATION:

- **Wall panels and objects about "clean" energy sources that could meet future needs:** Students can explore different ways to generate electricity, which include solar, wind, water, geothermal, and nuclear power.
- **Theater:** Students can watch this video to discover how experts are thinking about the issue of climate change.
- **Leave Your Message:** Encourage students to comment on the issues and challenges of climate change.

GUIDING QUESTIONS:

- Why is "clean" electricity key to solving climate change?
- What do you think governments like ours should do?

Using panels like these to capture solar energy produces no greenhouse gases or pollution.

Answer Key to the Guiding Questions: **amnh.org/resources/rfl/web/climatechangeguide/questions.html**

back in the CLASSROOM

Discuss the Exhibition

Use these conversation starters to build on what your students learned at the Museum:

- What did you learn about climate change that surprised you?
- How does climate change affect the world around us?
- How could your life change as our planet warms?
- What did you learn about our energy use? What would your life be like with less electricity?
- How do your actions affect how much energy you use? What could you do to save energy and lower CO_2 emissions?

Simple acts like switching to energy-saver light bulbs reduce energy consumption and CO_2 emissions.

Classroom Activities

Energy Conservation: Have students list ways in which they can save energy and lower CO_2 emissions. For ideas, visit **Be an Energy Saver** (**amnh.org/ology/energysaver**). As an extension, have students brainstorm ways to encourage their schoolmates, friends, and families to join the effort. How could students promote the program (e.g., a campaign with flyers, posters, school assembly presentations, and/or letters to local politicians or businesspeople)?

Energy Conservation in School: Ask students to survey how your school uses energy. Brainstorm energy-saving strategies (e.g., switching to Energy Star products, keeping thermostat settings lower in the winter and higher in the summer, car pooling). Encourage them to present the report to your principal.

Imagining Solutions: Review with students the various energy solutions from the exhibition (**amnh.org/climatechange**). Point out that the demand for energy will continue to rise, and that we need to produce more "clean" energy to meet the need and to lower CO_2 emissions. Have student teams brainstorm innovations—from ideas to inventions, and individual actions to nationwide initiatives—that could address this energy dilemma.

Online Resources

- ***Climate Change* exhibition:** amnh.org/climatechange
  Access the exhibition text and images before or after your visit.
- **Climate Change for Educators:** amnh.org/education/climatechange
  Find free online resources, including downloadable activities such as "Climate Change Circle of Consequences," "Environmental Alphabet," and "Using Solar Energy."
- **Climate Change OLogy:** amnh.org/ology/climatechange
  Younger students can explore big ideas about climate change and energy use, find energy-saving tips, and build a terrarium.
- **Science Bulletins:** amnh.org/sciencebulletins
  Through videos and interactives, middle and high school students can learn about current research into melting ice and rising sea levels. Click on the "Climate Change" tab at the top right.
- **Environmental Protection Agency Personal Emission Calculator:** epa.gov/climatechange/emissions/ind_calculator.html
  Students can use this online calculator to estimate their or their family's rate of greenhouse gas emissions.

credits

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Climate Change: The Threat to Life and A New Energy Future

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American Museum of Natural History

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MAP of the exhibition

1. Introduction

This area charts the dramatic rise of atmospheric carbon dioxide (CO_2) over the past 400 years and its link with industrial activity and population growth.

2. Climate Change Today

This area explains how the burning of fossil fuels to generate energy releases CO_2 into the atmosphere, and that this is causing Earth's climate to warm.

3. Making a Difference

Conserving energy is essential, and there are many ways for individuals to go about it. This area describes changes that can make a difference—if many act.

4. Changing Atmosphere

This area explains how scientists know that Earth's atmosphere is changing, and some of the expected effects.

5. Changing Ice

Ice is melting at the poles, and glaciers are shrinking. This area describes the present and possible future impact upon the world around us.

6. Changing Ocean

The ocean plays a vital role in climate by storing heat and carbon. This area explains the effects of higher CO_2 levels and warming temperatures on marine systems.

7. Changing Land

This area explores the effect of climate change on land. Droughts and floods may become more common, with consequences for ecosystems and human society.

8. A New Energy Future

This area describes options for meeting the world's increasing demand for energy while reducing CO_2 emissions.

CONNECTIONS to other museum halls

Find out more about Earth's climate system. Here are some good places to look throughout the Museum (all are on the first floor):

Gottesman Hall of Planet Earth

- **"Earth Cycles" wall:** Examine diagrams of the rock, water, and carbon cycles to learn more about how carbon and energy are connected in these three Earth cycles.
- "**What Causes Climate and Climate Change?" wall:** The long panel on one side illustrates how solar energy circulates through the atmosphere, and the ocean-atmosphere connection. A video in the middle of the panel explains the dramatic effects of El Niño on weather patterns. Opposite, check out the different kinds of evidence of past climate change (an ice core, tree rings, glacial striations).

North American Forests

- **"Giant Cactus Forest" and "Timberline in the Northern Rocky Mountains" dioramas:** Look at the ways in which the plants in these dioramas have adapted to their environments. What changes might a warmer climate bring to the timberline?
- **"Stories a Stump Can Tell" display:** Scientists study tree rings like the ones in this case for evidence of past climate. What factors besides climate can affect tree growth?

Warburg Hall of New York State Environment

- **"Glaciation" display:** An ice sheet once covered much of New York State. What signs of glaciation can you find across the street on the rocks of Central Park?

Hall of North American Mammals

- "**Bighorn Sheep" and "White Sheep" dioramas:** Climate change affects species in many different ways. How are animals in these dioramas adapted to their environments? How might they be affected by warming temperatures?
- "**Extinct American Mammals of the Ice Age" miniature dioramas** (on both sides of the main entrance)**:** Explore regions of California and Alaska 15,000 years ago, when Earth's average temperature was much cooler than it is now. Some of these animals have vanished, while others have near relatives living in the New World. Can you name any of those relatives? Where do they live today?

Hall of Biodiversity

- **"Urbanization and Agriculture," "Increasing Resource Demands," "Deforestation," and "Global Environmental Change" wall panels** (corridor behind the forest diorama)**:** Examine examples of how human activities have altered global systems. Compare consumption patterns in the United States to those in other countries.

Spitzer Hall of Human Origins

- **"Life During the Ice Age" display:** 15,000 years ago, humans coped with the cold in various ways. How might we change our clothing or housing, and even our ways of life, to adapt to a warmer world?

BEFORE YOU VISIT

grades 3-5

These discussion starters and activities are designed to spark your students' interest in the exhibition and to prepare them for the concepts they'll encounter.

Discussion Starters

WEATHER & CLIMATE

- How does the temperature change during the year where we live?
- What's your favorite weather?
- Have you visited friends or family who live in a different climate? How would you have to adapt if you moved there?

OUR ENERGY USE

- Between waking up and leaving home, how many switches did you flip?
- How many other ways did you use energy today?

Tips on Using the Student Worksheet

On the other side of this insert, you'll find a worksheet that your students can use to explore the *Climate Change* exhibition independently.

Before coming to the Museum, you may wish to distribute copies of the **Map of the Exhibition** and point out the areas that students will be exploring.

Activities

ALBEDO EFFECT

Objective: To understand how surface color affects the absorption of energy.

Procedure:

1. Ask students: On a hot summer day, would you want to wear a dark color shirt or a light one? Would it be more comfortable to walk barefoot on dark pavement or a light sidewalk?
2. Divide students into teams. Give each team one piece of white paper, one piece of dark paper, two thermometers, and a Temperature vs. Time chart.
3. Have teams put the two sheets of paper near a sunny window or under a desk lamp, and place a thermometer under each. Ask teams to take temperature readings every minute and record their findings on the chart.
4. Have teams present and compare their results.
5. Ask students: As more and more melting sea ice is replaced by dark ocean water, how might Earth's surface temperature change?

COMPARE LOCAL WEATHER AND CLIMATE

Objective: To understand the difference between weather and climate.

Procedure:

1. Over five days, distribute copies of the weather section from the newspaper or have students visit a weather website.
2. Each day, ask students to record and graph the following data for your area:
   - High and low temperatures
   - Record high and low temperatures
   - Average high and low temperatures
3. At the end of the week, have students analyze and discuss their data. Help them infer that the daily and record temperatures tell us about weather (the condition of the atmosphere at any given place or time), while the average temperatures describe climate (the typical long-term weather in a region from year to year).

STUDENT WORKSHEET grades 3-5

1. Investigate Our Energy Sources

In the **Introduction** area, find the steam engine. How did coal make the steam engine work?

Find the light bulb. Describe the connection between coal and the "Second Industrial Revolution" in 1882.

2. Investigate Our Energy Use

Find the big chunk of coal in the **Climate Change Today** area. It weighs one metric ton, or 2,200 pounds! If we burn it to generate electricity, it could . . .

. . . illuminate _____ 100-watt light bulbs for _____

. . . run a refrigerator for about _____

. . . produce about _____ of carbon dioxide (CO_2).

3. Investigate Weather and Climate

In the **Changing Atmosphere** area, look for the "Weather vs. Climate" wall.

What's the difference between weather and climate? _____

Describe the tools scientists use to study weather and climate. _____

4. What Can We Do?

Explore the **Making a Difference** area of the exhibition. On the back of this paper, list some things that you could do at home to save energy and lower your family's carbon dioxide (CO_2) emission.

BEFORE YOU VISIT

grades 6-8

These discussion starters and activities are designed to spark your students' interest in the exhibition and to prepare them for the concepts they'll encounter.

Discussion Starters

WEATHER & CLIMATE

- What's the difference between weather and climate?
- What are some recent news stories about climate change?
- What fruits and vegetables do you eat? Why do they grow in some places but not others?
- What tools do we use to measure weather conditions?
- Where would you look for clues to what climate was like in the past?

OUR ENERGY USE

- Describe the ways that you have used energy today.
- List the different sources of energy that are used to generate electricity in our area.
- Where do you think the energy that heats your home or school comes from?

Activities

CO_2 REMOVAL

Objective: To understand the role of plants in the carbon cycle.

Description: In this experiment, students use their breath, a carbon dioxide indicator, and a common water plant to show how plants remove CO_2 from Earth's atmosphere. Students then explore and discuss the impact of deforestation on climate change.

Download activity at: amnh.org/resources/rfl/web/climatechangeguide/activities/co2removal.html

SCIENCE BULLETINS: MELTING ICE, RISING SEAS

Objective: To understand how scientists use the scientific method to investigate Earth's warming climate.

Description: Students learn about the scientific method through class discussions and an online video. The video features scientists studying geologic records in Greenland's glaciers and Florida's fossilized coral reefs in order to predict the impact of melting ice on sea level rise.

Video and Essay available at: sciencebulletins.amnh.org
Click on the "Climate Change" tab at the top right. You'll find "Melting Ice, Rising Seas" among other stories in the right column. After you select the video and press "play," look for the "Educator Resources" link in the lower left column. It includes suggested questions to guide your class discussion and an in-depth look at the scientific method.

Tips on Using the Student Worksheet

On the other side of this insert, you'll find a worksheet that your students can use to explore the *Climate Change* exhibition independently. Before coming to the Museum, you may wish to distribute copies of the **Map of the Exhibition** and point out the areas that students will be exploring.

For Investigations 1 and 2, you can let students select which areas they would like to explore. Or, you can divide the class into four teams and assign each team an area of focus for both investigations.

STUDENT WORKSHEET grades 6-8

1. Investigate the Evidence for Climate Change

Select an exhibition area for your first investigation:

☐ **Changing Atmosphere** ☐ **Changing Ice** ☐ **Changing Ocean** ☐ **Changing Land**

Locate a piece of evidence that shows Earth's climate is changing. Evidence can include samples (e.g., tree rings ice cores, brain coral), charts, and maps. Use the back of this page to record your responses to these questions:

- What is the evidence?
- Sketch and label it.
- How did scientists collect the evidence? What tools were used?
- What question about climate change does this evidence help us answer?

2. Investigate the Consequences of Climate Change

Select an exhibition area for your second investigation:

☐ **Changing Atmosphere** ☐ **Changing Ice** ☐ **Changing Ocean** ☐ **Changing Land**

Describe a way in which climate change affects human society. _____

_____

Choose a plant or animal (including humans). Describe how it has been or might be affected by warming temperatures.

_____

_____

3. What Can We Do?

Explore the **Making a Difference** area. What actions can your school or community take to reduce carbon dioxide (CO_2) emissions?

_____

_____

_____

_____

BEFORE YOU VISIT

grades 9-12

These discussion starters and activities are designed to spark your students' interest in the exhibition and to prepare them for the concepts they'll encounter.

Discussion Starters

CLIMATE CHANGE

- What are some recent news stories about climate change?
- What conditions—such as the average temperature or the amount of rainfall—change as climate changes?
- Describe how organisms might respond to these changes.
- How would a rise in sea level affect where we live (e.g., housing, transportation)?

ENERGY USE

- Where does the energy that we use come from?
- What are some recent news stories about energy use—locally, nationally, or globally?

Activities

HOW GREENHOUSE GASES ABSORB HEAT

Objective: To understand that CO_2 absorbs heat in the atmosphere.

Description: In this experiment, student teams will compare the way two "atmospheres," one higher in CO_2, trap heat. Materials include jars, thermometers, baking soda, vinegar, tubing, and stoppers.

Download activity at:
amnh.org/resources/rfl/web/climatechangeguide/activities/gasestrapheat.html

SCIENCE BULLETINS: CLIMATE CHANGE STORIES

Objective: To explore current research related to climate change.

Description: Students can choose from an array of videos, interactives, and essays that explore cutting-edge scientific research on climate change. Stories include "Bio Snapshot: Climate Change Affects Ecosystems," "Earth Feature: Melting Glaciers, Clues to Climate Change," "Human Snapshot: Did Climate Change Guide Early Migrations?," and "Earth Viz: Sea Ice 2000-2008."

Videos, Interactives, and Essays available at:
sciencebulletins.amnh.org
Click on the "Climate Change" tab at the top right. Select a video or interactive and press "play." In the lower left column, you'll find supporting resources such as essays, interactives, data, and/or educator resources.

Tips on Using the Student Worksheet

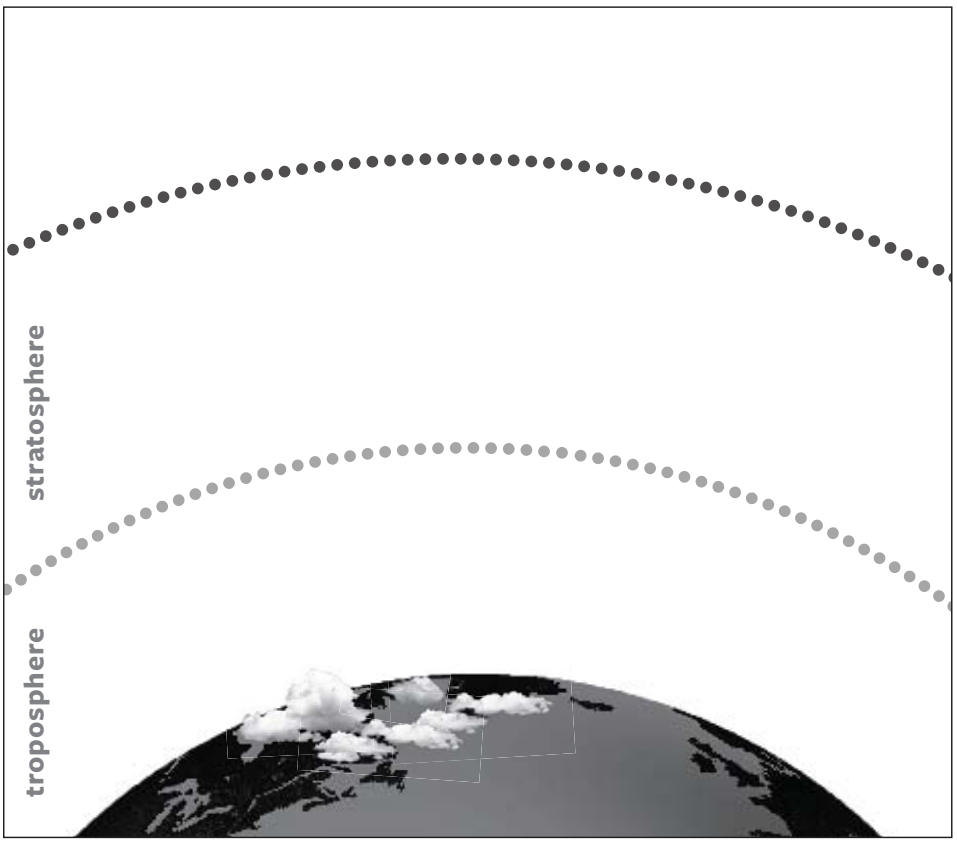
On the other side of this insert, you'll find a worksheet that your students can use to explore the *Climate Change* exhibition independently.

Before coming to the Museum, you may wish to distribute copies of the **Map of the Exhibition** and point out the areas that students will be exploring.

STUDENT WORKSHEET grades 9-12

1. Investigate How Climate Works

Find the Greenhouse Effect wall in the **Climate Change Today** area. On the diagram, add arrows that show energy flow.



Next, find the animated globe in each of these four areas:

- **Changing Atmosphere**
- **Changing Ice**
- **Changing Ocean**
- **Changing Land**

For each globe, choose and watch an animation. Record your responses to the questions below on the back of this page.

- Describe the phenomenon that you see in the animation.
- How is it connected to the climate system?

2. What Can We Do?

Explore the **Making a Difference** area. What actions can your school or community take to reduce CO_2 emissions?

3. Investigate Energy Solutions

Go to the **A New Energy Future** area and explore the various "clean" energy sources that could meet future needs. Record your responses to the questions below on the back of this page.

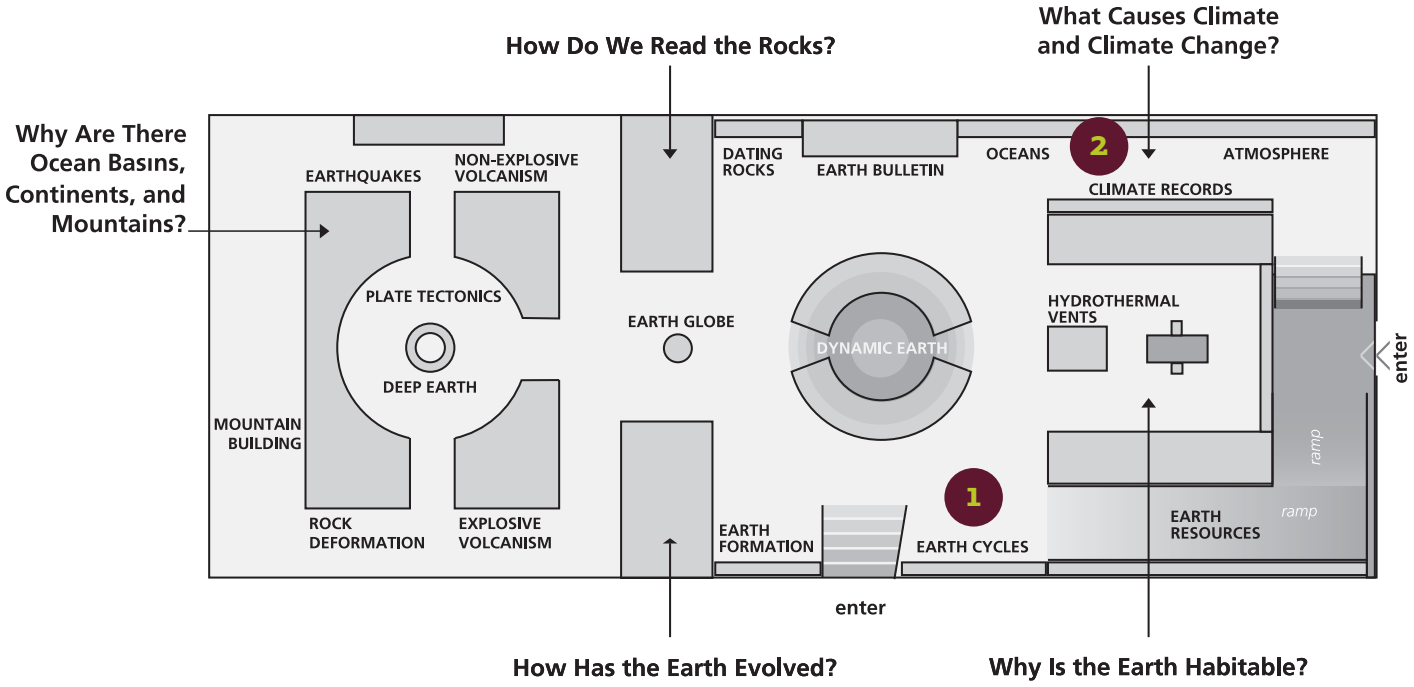
- Why is "clean" electricity key to solving climate change?
- What do you think governments like ours should do?

EXPLORE CLIMATE CHANGE
in the Gottesman Hall of Planet Earth

amnh.org

You can use the map and guiding questions below as you and your students move through the hall.

Students can also explore the exhibition independently or in pairs, using the Student Worksheet on the reverse of this page. Allow 10–15 minutes for independent investigation. Then gather students and ask them to share their evidence and how it advances our understanding of climate change.



1 Earth Cycles

Have students examine diagrams of the rock, water, and carbon cycles to learn more about their fundamental connections to the climate system.

GUIDING QUESTIONS:

- What connections do you see between the rock, water, and carbon cycles?
- Where does the energy come from?
- How does energy move through system?

2 What Causes Climate and Climate Change?

Have students explore the long panel that illustrates how solar energy circulates through the atmosphere and the ocean. They can also watch a video in the middle of the panel that explains the dramatic effects of El Niño on weather patterns. Opposite, ask students to examine the different kinds of evidence of past climate change.

GUIDING QUESTIONS:

- How does energy move through the atmosphere-ocean system?
- How has climate changed over time?
- How do we know how climate has changed in the past?

EXPLORE CLIMATE CHANGE
in the Gottesman Hall of Planet Earth

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Student Worksheet

Scientists investigate how Earth works by collecting and analyzing data. In the Gottesman Hall of Planet Earth, you can find many different kinds of data about Earth systems.

Find the **What Causes Climate and Climate Change?** area of the hall. Choose two topics that interest you, and find the evidence that supports our understanding of this part of the climate system. Record your findings below.

Example 1

What are scientists investigating?

What tools did they use?

What are the variables?

Insert the variables:

How will _____

affect _____

_____ ?

Make a sketch of the evidence (e.g., map, graph, specimen).

Example 2

What are scientists investigating?

What tools did they use?

What are the variables?

Insert the variables:

How will _____

affect _____

_____ ?

Make a sketch of the evidence (e.g., map, graph, specimen)

Climate Change Educator's Guide

Teaching in the Exhibiton: Answers to Guiding Questions

Use the Guiding Questions in the Teaching in the Exhibition section as a springboard for discussion, which may go in many directions. The answers below summarize key concepts of the exhibition. For more information, visit the exhibition website at **amnh.org/climatechange**.

1. Introduction

Why is atmospheric CO_2 on the rise?

Levels of atmospheric carbon dioxide (CO_2) are climbing mostly because humans are burning fossil fuels in ever-increasing amounts — an activity that releases carbon dioxide. The increase began when coal replaced wood as a common fuel, and was spurred by the invention of the steam engine. CO_2 emissions have accelerated even more over the last 150 years with the commercial production of electricity from coal.

How are different kinds of machines powered?

Machines are powered by different kinds of fuel, including oil (which includes gasoline and diesel fuels), ethanol, and electricity. Our world runs on electrical power, and much of that power comes from coal.

How have different kinds of carbon-based technologies affected human societies?

Carbon-based technologies have vastly improved our lives. Labor once performed by humans is now carried out by machines. Harnessing electricity provided safe, bright light — and energy. Steam engines powered trains and boats, and oil-based power cars and planes move us comfortably around the world. Electronic devices, including personal computers and mobile phones, have transformed the way we work and communicate.

2. Climate Change Today

How do greenhouse gases affect Earth's atmosphere?

The atmosphere is a transparent, protective blanket that admits enough of the Sun's energy to warm our planet. Greenhouse gases in the atmosphere — carbon dioxide (CO_2), water vapor, methane, and nitrous oxide — retain some of this heat. Without this greenhouse effect, Earth's surface would be frozen and probably lifeless.

What human activities are causing the atmosphere to warm?

Human activity, particularly the burning of fossil fuels, creates greenhouse gases. Burning coal to generate electricity is the most significant source of this CO_2.; deforestation also plays a part. Humans are withdrawing carbon — in the form of coal and oil — from the long-term rock reservoir in which it sat for tens of millions of years, and pumping vast amounts of it into the surface reservoirs — the atmosphere, ocean, and biosphere. The increasing CO_2 content of the atmosphere is causing it to absorb and hold more heat emitted by Earth's surface.

3. Making a Difference

What can you do to conserve energy and reduce CO_2 in the atmosphere?
There are many ways to reduce you and your family's energy use. Switch to compact fluorescent light bulbs, install energy-efficient appliances, and turn off appliances and electronics when not in use. Take shorter showers. Drive less; instead, ride your bike or take public transportation, and carpool when you can. In the winter, dress more warmly instead of turning up the thermostat; keep blinds and curtains closed at night and open during the day. In the summer, raise the thermostat to 78, and turn on a ceiling fan instead of the AC.

How could you and others work together to broaden the effect of your actions?
You could conduct school- or community-wide campaigns — using leaflets, posters, or announcements in school assemblies — that promote the activities listed above. Work with local organizations to promote public transportation, tree-planting, energy-efficient construction, and large-scale recycling programs. Get involved in Earth Day and other renewable-energy or conservation-oriented activities.

4. Changing Atmosphere

What's the difference between weather and climate?
Weather describes the conditions today, tomorrow, or in the days to come. Climate is the average weather over years or longer.

What are some ways in which climate change affects weather?
Warming may change wind and weather patterns, generally bringing more rain to ocean areas and less to land.

What's the evidence that Earth's atmosphere is changing?
Cores drilled through ice caps contain samples of the different gases that made up the air when the ice solidified. These atmospheric "time capsules" show that there is more CO_2 in the atmosphere than at any time over the past 800,000 years — and probably much longer.

What are some of the consequences of a warming atmosphere take?
Intense storms have and are expected to become more common, heat waves are likely to become more frequent and intense, and we can expect more droughts and floods.

5. Changing Ice

How will melting ice affect the world around us?
Sea levels will rise. Low-lying land will experience erosion and become submerged, and coastal areas will experience more flooding during storm surges, with devastating consequences for the hundreds of millions of people who live near the ocean.

What role do seasonal changes in snow and ice cover play in Earth's climate?
The bright white of ice and snow reflects the Sun's radiant energy back into space. Much of this takes place at the high latitudes, where ice and snow cover builds up during the winter and shrinks during the summer. More of that cover disappears when summers are long and warm. The more ice and snow that survive the summer, the cooler Earth stays.

Why is the Arctic so sensitive to climate change?
The North Pole is significantly warmer than the South Pole because it's in the middle of an ocean. Long, warm summers decrease snow and ice cover and expose the dark water, which absorbs far more solar energy. As a result, the Arctic is heating up twice as fast as the rest of the Northern Hemisphere. On the other hand, Antarctica is less affected by climate change because it's much colder; its climate is insulated from the rest of the world by circumpolar ocean currents. Also, most Antarctic ice sits on land rather than water, so it's less vulnerable to warming ocean temperatures.

6. Changing Ocean

How do scientists study ocean temperature and chemistry?
Many ships measure water temperature and chemistry as they travel across the oceans. Scientists also rely on satellites to measure sea surface height (which corresponds to temperature), and outfit buoys, floats, and ocean gliders to measure temperature, pH, salinity, or CO_2 content.

Why is the ocean so important to Earth's climate?
The ocean plays a key role in the climate system because it holds far more CO_2 than the atmosphere or biosphere. Ocean waters absorb CO_2 directly from the atmosphere, and some ocean organisms take up CO_2 as they grow. Will climate change affect the ocean's ability to remove CO_2 from the atmosphere and thus intensify greenhouse warming? We do not know.

How might changing conditions affect marine ecosystems?
About 30 percent of the CO_2 released by humans over the past 200 years has been absorbed by ocean waters. This has changed the chemistry of the water, making it less basic: the sea is "acidifying." Ocean acidification could make it harder for shell-forming organisms, from corals to tiny plankton, to grow their shells. Eventually, shell-forming organisms could disappear.

7. Changing Land

Why will both droughts and floods become more common?
When warm air passes over land, moisture evaporates from the soil, drying it out. At the same time, warming will likely change weather patterns, bringing much less precipitation to certain parts of the world. On the other hand, when water evaporates from Earth's surface, particularly the ocean, it adds a significant amount of energy as well as water vapor to the atmosphere. The result is storms that are less frequent but unusually strong.

What are some of the ways that climate change is affecting organisms?
Some species are shifting their geographic ranges to higher elevations. Changes in temperature and rainfall patterns are enabling others to spread more widely. Some are blooming, migrating, or breeding earlier. While some organisms can adjust to climate change, others cannot. Tropical species, which typically can survive only within a narrow temperature range, are especially at risk.

8. A New Energy Future

Why is clean electricity key to solving climate change?

Plants the produce electricity are responsible for more than 30 percent of global CO_2 emissions each year, by far the largest source of those emissions. In addition, CO_2 emissions from electricity production are growing much faster than emissions from other sources.

What do you think governments like ours should do?

Answers will vary. They may include:

- Directly tax carbon emissions
- Develop a cap-and-trade system (which gives companies an economic incentive to reduce emissions)
- Invest in alternative energy technologies
- Raise fuel-efficiency standards for trucks and cars
- Build public transportation systems
- Give tax breaks to homeowners who use less energy
- Support research on renewable energy
- Give scholarships in environmental science
- Give prizes for innovation in green buildings and sustainable development
- Protect forests, plant trees, and work to prevent deforestation worldwide
- Work with governments around the world to protect shared resources like the oceans and the atmosphere

Climate Change Educator's Guide

Answers to Student Worksheets

Grades 3-5

1. Investigate Our Energy Sources

Find the steam engine. How did coal make the steam engine work?
Burning coal boils water, which makes steam. The steam, which is held in a boiler under high pressure, pushes a piston that powers an engine.

Find the light bulb. Describe the connection between coal and the "Second Industrial Revolution" in 1882.
The "Second Industrial Revolution" started when power plants — fueled by burning coal — began bringing electricity to factories, offices, and homes.

2. Investigate Our Energy Use

Find the big chunk of coal in the Climate Change Today area. It weighs one metric ton, or 2,200 pounds! If we burn it to generate electricity, it could . . .

. . . illuminate **22,000** 100-watt light bulbs for
. . . run a refrigerator for about **2** years
. . . produce about **2.5 metric tons** of CO_2 (carbon dioxide).

3. Investigate Weather and Climate

What's the difference between weather and climate?
Weather describes the conditions over the next few days. Climate describes the average weather over many years.

Describe the tools scientists use to study weather and climate.
Scientists use satellites, buoys and floats, and ocean gliders.

4. What Can We Do?

List some things that you could do at home to save energy and lower your family's carbon dioxide emission.
Answers will vary. They may include: Switch to compact fluorescent light bulbs, install energy-efficient appliances, and turn off appliances and electronics when not in use. Take shorter showers. Ride in cars less; instead, ride your bike or take public transportation. In the winter, dress more warmly instead of turning up the thermostat; keep blinds and curtains closed at night and open during the day. In the summer, raise the thermostat to 78°, and turn on a ceiling fan instead of the AC.

Grades 6-8

1. Investigate the Evidence for Climate Change

Answers may vary. Types of evidence include ice core, tree rings, brain coral fossil, and sediment core.

2. Investigate the Consequences of Climate Change

Describe a way in which climate change affects human society.
Answers will vary. They may include: Droughts could disrupt agriculture, causing starvation. Storm surges and rising sea levels could displace the hundreds of millions of people who live on or near seacoasts. Changes in temperatures and the distribution of rainfall could lead to disease outbreaks.

Choose a plant or animal (including humans). Describe how it has been or might be affected by warming temperatures.
Answers will vary. They may include: Melting Arctic sea ice and permafrost (frozen land) is disturbing the places where many polar animals hunt, nest, and breed. Changes in ocean water threaten populations of phytoplankton. These microscopic plants form the base of the ocean's complex food chains, so this could affect animals throughout the ocean.

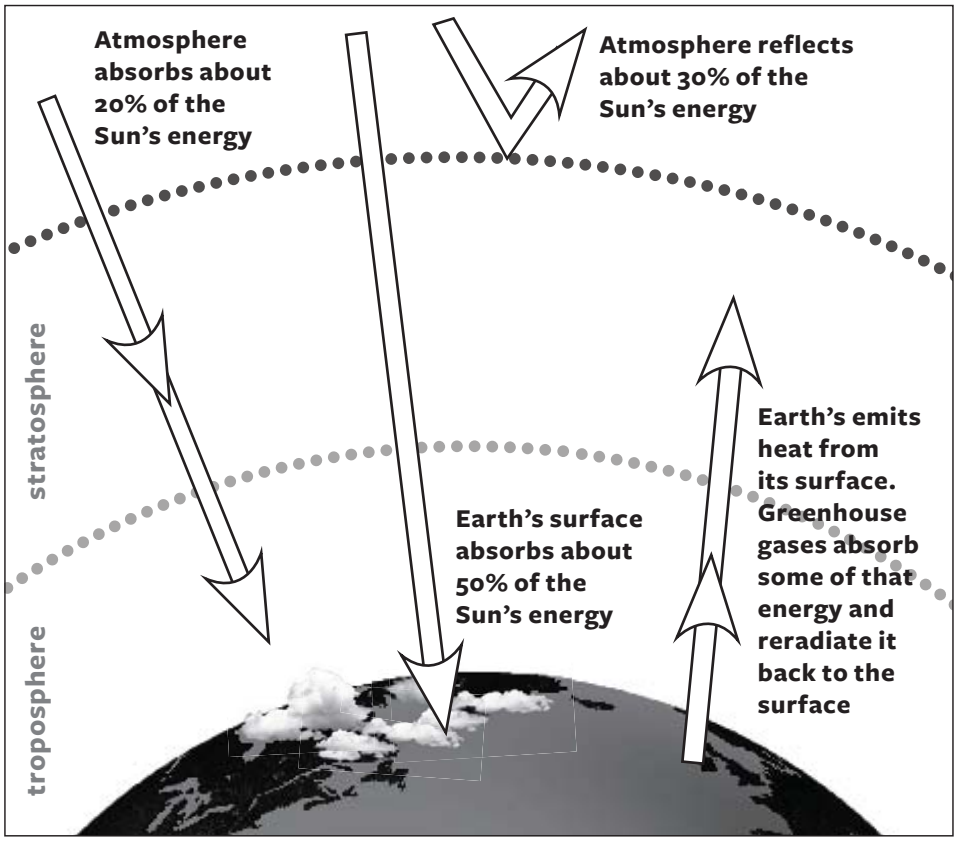
3. What Can We Do?

What actions can your school or community take to reduce carbon dioxide emissions?
Answers will vary. They may include: Conduct school- or community-wide campaigns — using leaflets, posters, or announcements in school assemblies — that promote actions that individuals can take to slow climate change. Work with local organizations to promote public transportation, tree-planting, energy-efficient construction, and large-scale recycling programs. Get involved in Earth Day and other renewable-energy or conservation-oriented activities.

GRADES 9-12

1. Investigate How Climate Works

Answers will vary. They may include: Clouds in the atmosphere help control temperatures on Earth by reflecting and absorbing light and heat coming into and leaving our planet. The ice-covered poles reflect the Sun's energy, and the huge temperature difference between the frozen poles and the equator drives wind and ocean currents. Evaporation of ocean waters brings moisture to land areas and transfers energy to the atmosphere where it helps drive weather systems.



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What do you think governments like ours should do?
Answers will vary. They may include: Directly tax carbon emissions. Invest in alternative energy technologies. Raise fuel-efficiency standards for trucks and cars. Build public transportation systems. Give tax breaks to homeowners who use less energy. Support research on renewable energy. Give prizes for innovation in green buildings and sustainable development. Protect forests, plant trees, and work to prevent deforestation worldwide. Work with governments around the world to protect shared resources like the oceans and the atmosphere.

Explore Climate Change in the Hall of Planet Earth

Answers will vary. They may include: Scientists study a marine sediment core from the tropics to understand seasonal changes in biological activity in the waters from which the sediments were deposited. Light layers, formed during winter, are richer in biologically produced carbonate, while dark layers, formed during summer, contain fewer biologically produced sediments and more silts and clays. The nearly 3,000 years spanned by this sediment core includes the onset of the Younger Dryas, a cold period marked in the core by a general lightening of sediment color, the direct result of increased biological productivity.