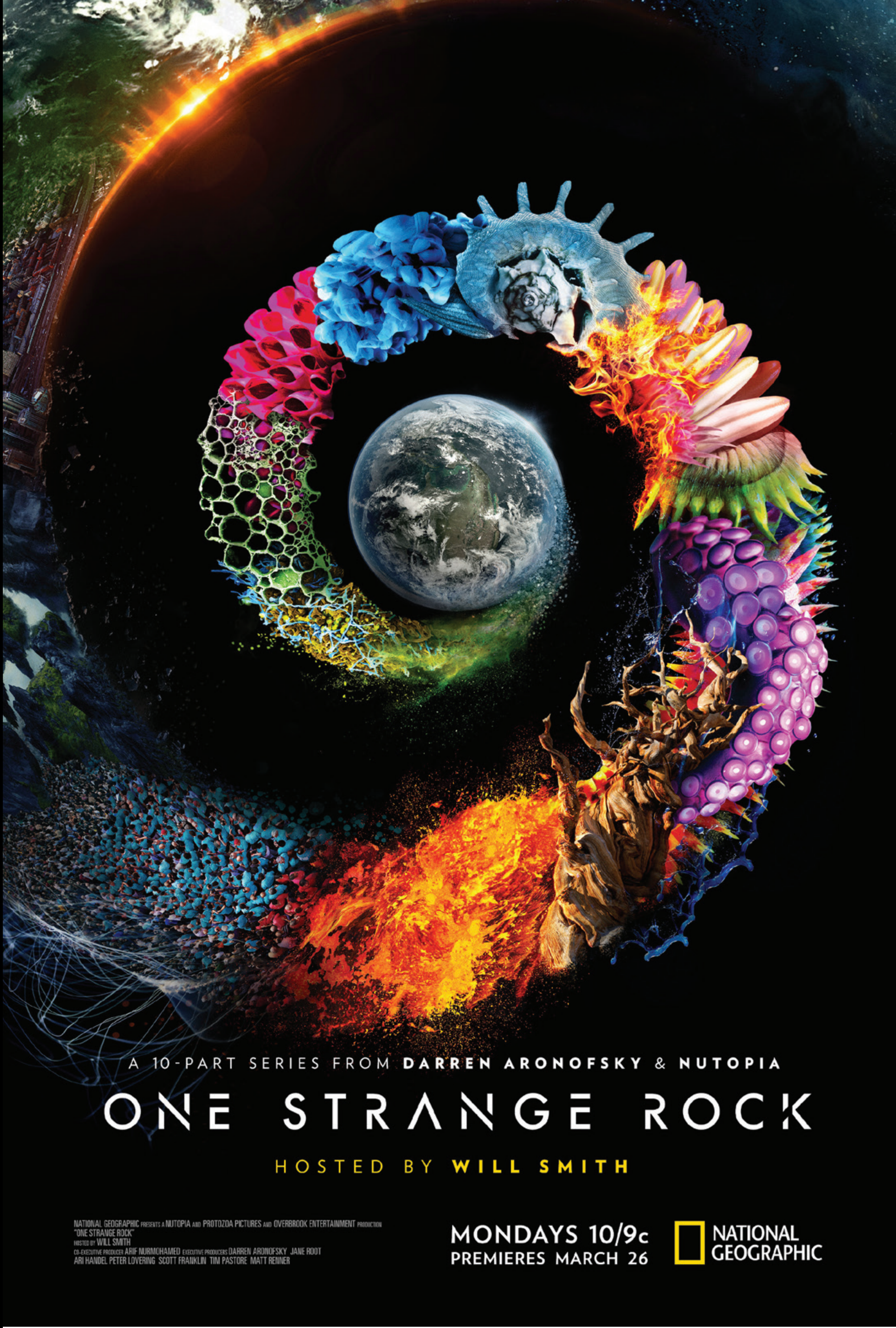
# Climate Lesson: The Air We Breathe

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# The Air We Breathe

## Enduring Understandings

- The changes in our Earth's climate have both natural and man-made causes. However, the scientific data support that the recent dramatic climate changes are human-driven.
- The scientific methods used to discover what was happening to the Earth thousands of years ago are understandable, attainable, and repeatable.
- Since the problem has been human-driven, so is the solution. A social change is required to help bring the Earth back into its natural cyclical pattern.

## Essential Questions

- How do we reduce the human impact on global climate change?
- What is global climate change? How has it changed due to human influence?
- What areas of our lives are affected most by climate change?
- What are the scientific principles involved with capturing ice core data?
- How does the Keeling curve affect our understanding of the causes of climate change?
- How can we spread awareness and reduce our carbon footprint?

**Notes to the Teacher**

The following excerpt was taken from the NASA Global Climate Change website https://climate.nasa.gov/ to provide a brief introduction and background for the teacher on the facts surrounding climate change. This source and others listed on the site and in the Additional Resources section will be useful throughout the lesson.

> *The Earth's climate has changed throughout history. Just in the last 650,000 years there have been seven cycles of glacial advance and retreat, with the abrupt end of the last ice age about 7,000 years ago marking the beginning of the modern climate era — and of human civilization. Most of these climate changes are attributed to very small variations in Earth's orbit that change the amount of solar energy our planet receives.*
>
> *The current warming trend is of particular significance because most of it is extremely likely (greater than 95 percent probability) to be the result of human activity since the mid-20th century and proceeding at a rate that is unprecedented over decades to millennia.*
>
> *Earth-orbiting satellites and other technological advances have enabled scientists to see the big picture, collecting many different types of information about our planet and its climate on a global scale. This body of data, collected over many years, reveals the signals of a changing climate.*

> *The heat-trapping nature of carbon dioxide and other gases was demonstrated in the mid-19th century. Their ability to affect the transfer of infrared energy through the atmosphere is the scientific basis of many instruments flown by NASA. There is no question that increased levels of greenhouse gases must cause the Earth to warm in response.*
>
> *Ice cores drawn from Greenland, Antarctica, and tropical mountain glaciers show that the Earth's climate responds to changes in greenhouse gas levels. Ancient evidence can also be found in tree rings, ocean sediments, coral reefs, and layers of sedimentary rocks. This ancient, or paleoclimate, evidence reveals that current warming is occurring roughly ten times faster than the average rate of ice-age-recovery warming.*[1]

The NASA site then provides a list of topics that you and your students can explore regarding the evidence that supports rapid climate change, including:

1. Global temperature rise
2. Warming oceans
3. Shrinking ice sheets
4. Glacial retreat
5. Decreased snow cover
6. Sea level rise
7. Declining Arctic sea ice
8. Extreme events
9. Ocean acidification

This lesson is designed to teach students about anthropogenic climate change and possible solutions to the problem. Topics include photosynthesis, Keeling curve, ice core data, sediment cores, evidence to support climate change, human behavior and lifestyle, and how to raise awareness to promote change.

The National Geographic series *One Strange Rock* has five episodes that are particularly relevant to this lesson: "Home," "Survival," "Terraform," "Shield," and "Gasp." Try to show as many as time permits in conjunction with the lesson. Be sure to allow sufficient time for student discussion and questions.

The lesson is divided into four parts that build on one another based on time and subject material. The first part introduces students to photosynthesis and the air they breathe. It is geared to teach students the basic inputs and outputs of photosynthesis and the light-dependent and light-independent reactions. This will help students understand that plants do not convert carbon dioxide into oxygen as many people believe. Instead, the oxygen they breathe comes from the splitting of water, and the carbon dioxide is transformed into structural and energy molecules needed by the plant. This section could take one to two days based on the level of detail for photosynthesis required for your students. You should watch the video from Paul Anderson's Bozeman Biology site on photosynthesis at https://www.youtube.com/watch?v=g78utcLQrJ4 ahead of time, prepare notes for class discussion, and have a few packs of sticky notes before class.

Part 2 allows for lab-based explorations to help students understand how the ice core data are collected. Students have opportunities to problem-solve, design a solution, and build a model that most effectively captures carbon dioxide. This

1 https://climate.nasa.gov/evidence/

part should take a full two days and will require a table of spare parts for students to design their own $CO_2$ chambers. You may also want to add a day for students to present their models and explain the choices they made for their design.

Part 3 introduces students to the Keeling curve data set and has them complete basic climate change research. This is a critical step to prepare students for the student activism project as it lays the groundwork to begin to understand the complexities of climate change science and the evidence that attributes the most recent dramatic changes in carbon dioxide concentrations to human activities. This part will take three days and will require copies of **Handout 1, Handout 2, and Handout 3** for each student. There are corresponding Teacher Resource pages after each handout that will guide you in class discussions.

The final part will take four to seven days, depending on how much work is assigned outside of class. After a class brainstorming session, students will choose a topic they will work on to create positive change regarding climate change. Students will research how their topics affect global change and submit a proposal for their project work. The teacher will consult with students, approve their plans, and make adjustments as necessary. The student proposals should articulate plans to share information with others outside of the classroom (the public) and document how they are promoting positive change. When students have completed their project work, they will share with the class in small groups or whole class presentations. Inviting administration, families, or local business leaders would help to show the importance of the work and support for the students. Audience members may participate by providing questions and meaningful feedback to each presenter/group.

### Common Core Standards addressed by this lesson

**CCSS.ELA-Literacy.RST.9-10.1**
Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

**CCSS.ELA-Literacy.RST.9-10.3**
Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

**CCSS.ELA-Literacy.RST.9-10.7**
Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

**CCSS.ELA-LITERACY.RH.11-12.7**
Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, as well as in words) in order to address a question or solve a problem.

**CCSS.MATH.CONTENT.HSF.IF.B.4**
For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship.

**CCSS.MATH.CONTENT.HSF.IF.B.5**
Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.

**CCSS.MATH.CONTENT.HSF.IF.B.6**
Calculate and interpret the average rate of change of a function (presented symbolically or as a table) over a specified interval. Estimate the rate of change from a graph.

## NGSS Standards addressed by this lesson

Downloaded from the NGSS website at https://www.nextgenscience.org/

**HS.Interdependent Relationships in Ecosystems**
Students who demonstrate understanding can:

**HS-LS2-6.**
Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. [Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood, and extreme changes, such as volcanic eruption or sea level rise.]

**HS-LS2-7.**
Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]

**HS-LS4-6.**
Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity. [Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species or to genetic variation of organisms for multiple species.]

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education.

**Science and Engineering Practices**

*Constructing Explanations and Designing Solutions*
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-LS2-7)

**Disciplinary Core Ideas**

*LS2.C: Ecosystem Dynamics, Functioning, and Resilience*
- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-2),(HS-LS2-6)
- Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. (HS-LS2-7)

*LS4.D: Biodiversity and Humans*
- Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (secondary to HS-LS2-7)
- Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (secondary to HS-LS2-7), (HS-LS4-6)

**NGSS Standards: addressed by this lesson**

***ETS1.B: Developing Possible Solutions***

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (secondary to HS-LS2-7),(secondary to HS-LS4-6)
- Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical, and in making a persuasive presentation to a client about how a given design will meet his or her needs. (secondary to HS-LS4-6)

**Crosscutting Concepts**

*Cause and Effect*

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS2-8),(HS-LS4-6)

*Scale, Proportion, and Quantity*

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-LS2-1)
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. (HS-LS2-2)

*Stability and Change*

- Much of science deals with constructing explanations of how things change and how they remain stable. (HS-LS2-6),(HS-LS2-7)

## Duration of the Lesson

Part 1: one to two class periods–Photosynthesis Brainstorm and Background

Part 2: one to two class periods–$CO_2$ Lab Explorations

Part 3: two to three class periods–Keeling Curve, Webquest, Ecological Footprint

Part 4: four to seven class periods–Student Activism Project and Presentations

## Assessments

Brainstorming notes

Handouts, webquest, and worksheets

Class discussions

Student or group project and presentations

## Materials needed

Sticky notes

**Handout 1: What Is the Keeling Curve?**

**Handout 2: Exploring Earth's History and Understanding Climate Change**

**Handout 3: What is Your Ecological Footprint?**

**Handout 4: Student Activism Project Proposal**

**Handout 5: Student Activism Project Assignment**

Whiteboard or overhead to record and display class ideas and questions

Table of spare parts for students to design $CO_2$ chambers (milk jugs, plastic containers, glue guns, scissors, etc.)

Computers with Internet access

*One Strange Rock* documentary

# Procedure

**Part 1. Photosynthesis Brainstorming and Background**

1. Begin class by asking students "Where does most of the matter of a tree come from?" Have students brainstorm a list of what makes up the tree, such as wood, bark, leaves, flowers, roots, and fruit, to have an idea of what makes up all the matter of a tree. Then brainstorm a list of possibilities of what plants need to grow. Accept all ideas at first and list them on the board. Students may say light, carbon dioxide, water, oxygen, chlorophyll, chloroplasts, minerals, soil, leaves, etc. Then have students write down the one choice that they think is the best answer on a sticky note. Help students create a bar graph on the class whiteboard with all of the choices.

2. Start a class discussion about the results to see what students know or remember about photosynthesis. You may be able to construct the basic photosynthesis chemical formula of inputs and outputs by working together as a group: light + carbon dioxide gas + water yields oxygen gas + glucose (food). This can then lead to writing the formula using the chemical symbols: $6\ CO_2 + 6H_2O +$ energy$\longrightarrow C_6H_{12}O_6 + 6O_2$.

3. Watch the video from Paul Anderson's Bozeman Biology site on photosynthesis https://www.youtube.com/watch?v=g78utcLQrJ4 and assign appropriate textbook reading for your level of student. The goal is to spend the next class day learning about the light-dependent and light-independent reactions of photosynthesis and to make sure students know when each reactant and product are utilized in the process.

4. Once you have covered photosynthesis, ask students if they would like to change their answer to the matter question or if they now know the correct response. The two big points to stress are that the oxygen we breathe comes from plants splitting water in the light-dependent reactions and that most of the matter of a tree comes from the carbon dioxide being fixed with the hydrogen from water in the light-independent reactions (Calvin cycle) making G3P, which serves as the basic building blocks for the plant's energy and structural needs.

**Part 2. $CO_2$ Lab Explorations**

1. Begin the class with the video "$CO_2$ in the Ice Core Record" at https://www.youtube.com/watch?v=oHzADl-XID8&t=102s. Upon completion, begin a classroom discussion about the idea of capturing trapped air from melting ice. Ask students, "How could we recreate these experiments to capture $CO_2$ levels at the high school (middle school) level?"

2. Explain that students will need to determine a way to capture and measure the $CO_2$ released when sodium bicarbonate tablets (Alka Seltzer) are dropped into normal tap water. You should have all available equipment out on the desk to show students what they will have to work with. This may or may not include a $CO_2$ sensor made by Vernier or Pasco among others. Have students brainstorm in groups.

3. Challenge students to come up with the most efficient way to capture and collect these data. Allow students time to discuss and come up with a plan.

4. Have students present and discuss their work. They should be prepared to discuss their findings and be able to elaborate on their choices in procedure. They may also want to incorporate "things that went well" and/or "suggestions toward future improvement."

5. The idea of the final challenge problem is to provide students a frame of reference for how scientists measure atmospheric gases released from 800,000-year-old ice. Students are duplicating scientific methods to reinforce how scientists can tell what was going on in the Earth's atmosphere so long ago.

**Part 3. Keeling Curve, Climate Change Webquest, and Ecological Footprint Activity**

1. Pass out **Handout 1: What Is the Keeling Curve?** and have students work with partners to analyze the graph and answer the questions. Students can finish for homework if they run out of time.

2. Have students report out their answers and discuss the difference between the carbon dioxide levels increasing overall as a result of increased fossil fuel burning and the annual increase and decrease as a result of deciduous trees leafing in the spring and senescing in the fall. Help students connect back to photosynthesis by showing them the formula and helping them to see the inputs and outputs of photosynthesis to understand why carbon dioxide levels drop in the spring/summer and increase in the fall/winter. Note that there are Teacher Resource sheets following each of the three handouts to guide you in class discussions.

3. (Optional) Explore photosynthesis labs with $CO_2$, $O_2$ probes, and baby spinach in a chamber. Expose the spinach to light and dark recording levels to see when the plant is doing cellular respiration and photosynthesis.

4. Start the research necessary for the Student Activism Project by having students work through the climate change webquest on **Handout 2: Exploring Earth's History and Understanding Climate Change** and then the **Handout 3: What is Your Ecological Footprint?** activity. (Complete the activities yourself ahead of time to anticipate student questions and help them navigate the websites. Work through your own ecological footprint to be able to share your results with the class.) Have students post their results on the board, so they can calculate a class average on step 4 of the worksheet.

**Part 4: Student Activism Project**

[Note: The period of time when students are planning their activism project independently is an excellent time to show episodes from *One Strange Rock* in your classroom. Be sure to allow adequate time for student discussion and questions. Suggestions for the most relevant videos for this lesson may be found in Notes to the Teacher.]

1. Begin class by posing the question to students: In what areas of our community/country/world should we make important changes in order to slow climate change? Start a class list to which they can add responses, and provide one example to start the list (for example, food, transportation, electricity, clothing, housing). Then instruct students to record three responses they might include on the list. Try to have each student contribute at least one idea.

2. When the list exceeds the number of students in the class or you're satisfied that the responses include the most important areas, assign each student one of the criteria as a topic for their project.

3. Distribute **Handout 4: Climate Change Activism Project Proposal** and **Handout 5: Climate Change: Student Activism Project**. Give students adequate time to research and plan their projects.

4. Meet with students to discuss their proposals and make adjustments as necessary.

5. After students have completed the Awareness Campaign and the Action Campaign, give them the opportunity to share what they have accomplished with the class in whole-class or group presentations.


Journeys in Film: One Strange Rock

Handout 1 ▸ P.1

# What Is the Keeling Curve?

**Directions:**

Review the graph on the next page carefully before you respond to the questions below. The jagged line represents the "monthly mean" and the relatively straight line represents the "long-term trend" of atmospheric carbon dioxide.

**1.** What do the data in this graph indicate? Be complete in your response.

**2.** The oldest available data point from the Keeling curve was from 1958 and had a readout of 315.70 ppm. The most current available data point is from 2017 and had a readout of 407.46 ppm. Calculate the average rate of change (slope) between these two data points. Interpret your results. Please remember to include units.

**3.** Why do you think the "monthly mean" line shows a single rise and fall each year? Explain your answer.

**4.** Why do you think the "long-term trend" line is steadily increasing? Use the terms and concepts you learned about the carbon cycle in your response.

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**Handout 1 ▸ P.2**

# What Is the Keeling Curve?

**5.** Why do you think the sharp drop in $CO_2$ levels occurs between the months of May and September/October?

**6.** What role does the Earth's vegetation play in shaping the annual $CO_2$ cycle of levels shown in the Mauna Loa data?

**7.** The Mauna Loa Observatory is located in the Northern Hemisphere, while other $CO_2$ observatories are located in the Southern Hemisphere. How different do you think the Southern Hemisphere $CO_2$ levels would be?

# What Is the Keeling Curve?

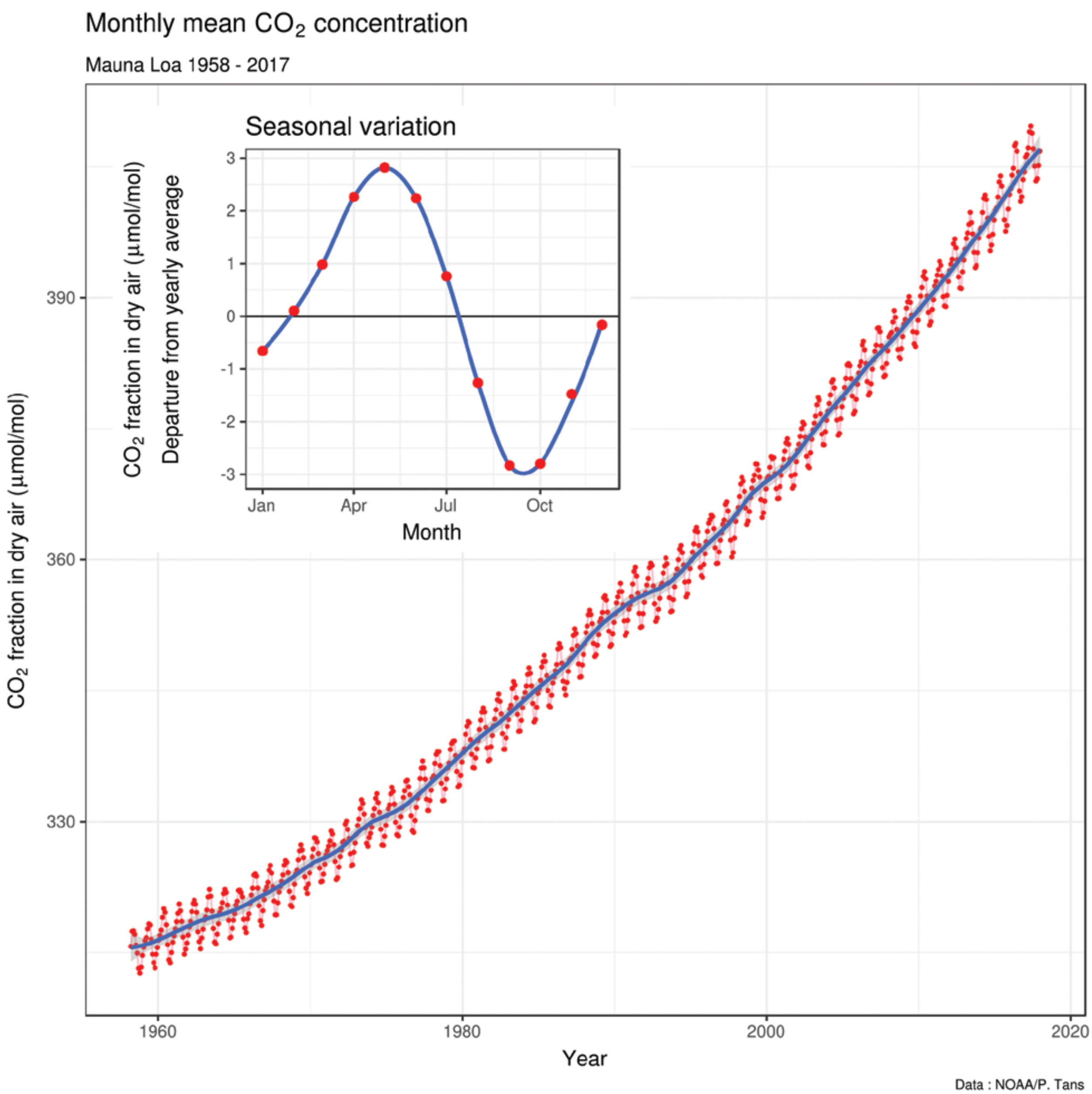


Figure 1. The "Keeling curve," a long-term record (1958-2017) of atmospheric $CO_2$ concentration measured at the Mauna Loa Observatory (Keeling et al.). The insert shows a single annual $CO_2$ cycle. Note that the annual $CO_2$ peak occurs in May and the lowest levels occur in September and October.

Source: Data from Dr. Pieter Tans, NOAA/ESRL and Dr. Ralph Keeling, Scripps Institution of Oceanography at https://commons.wikimedia.org/wiki/File:Mauna_Loa_CO2_monthly_mean_concentration.svg.

**Teacher Resource**
**1 ▸ P. 1**

# Answer Sheet for Handout 1

**1.** What do the data in this graph indicate? Be complete in your response.

*The data in the graph represent how much carbon is in the atmosphere in ppm each year since 1958. It shows a positive trend, since that amount is increasing from 1958 to 2017. Students can look up Charles David Keeling to learn more about the history of the data collection.*

**2.** The oldest available data point from the Keeling curve was from 1958 and had a readout of 315.70 ppm. The most current available data point is from 2017 and had a readout of 407.46 ppm. Calculate the average rate of change (slope) between these two data points. Interpret your results. Please remember to include units.

*To calculate the slope or rate of change, you need to subtract the two y-coordinates. After finding the difference between the amounts of* $CO_2$ *(407.46 – 315.70 = 91.76), you need to divide by the total number of years that have transpired, 59 (2017 – 1958 = 59). So 91.76 divided by 59 equals 1.555. This represents the average growth in* $CO_2$ *in ppm each year since they started to record the data.*

**3.** Why do you think the "monthly mean" line shows a single rise and fall each year? Explain your answer.

*The rise in* $CO_2$ *begins in October and continues until mid to late April, which corresponds with deciduous trees in the Northern Hemisphere losing their leaves and entering dormancy for the winter. The photosynthetic activity significantly drops, since the majority of Earth's vegetation (and deciduous trees) are in the Northern Hemisphere. Also, the decomposition of the fallen leaf material can result in* $CO_2$ *emissions from cellular respiration. The annual decline in* $CO_2$ *begins in April and continues to October, which corresponds with the trees and vegetation leafing out and converting* $CO_2$ *into glucose in the process of photosynthesis.*

**4.** Why do you think the "long-term trend" line is steadily increasing? Use the terms and concepts you learned about the carbon cycle in your response.

*See responses in Handout 2 for more information on human impact on the carbon cycle and climate change. Overall, the steady increase is a result of human activity, such as fossil fuel use for industry, heating, and transportation. Also, habitat conversion removes forests and vegetation. Both impacts result in a shift of sources and sinks moving more carbon into the atmosphere that was stored in the Earth and trees.*

**Teacher Resource 1 ► P.2**

# Answer Sheet for Handout 1

**5.** Why do you think the sharp drop in $CO_2$ levels occurs between the months of May and September/October?

*See Question #3. You may need to review photosynthesis and cellular respiration to help students understand the annual cycle.*

**6.** What role does the Earth's vegetation play in shaping the annual $CO_2$ cycle of levels shown in the Mauna Loa data?

*Similar to Questions #3 and #5. Encourage students to explore Earth's forests using Google Earth, other images, biome maps, etc. to see where the vegetation is located by hemisphere and where most of the deciduous forests are located. May need to review seasons for each hemisphere with students.*

**7.** The Mauna Loa Observatory is located in the Northern Hemisphere, while other $CO_2$ observatories are located in the Southern Hemisphere. How different do you think the Southern Hemisphere $CO_2$ levels would be?

*Answers may vary. Other sample sites around the globe have collected similar data to the Keeling curve. The Southern Hemisphere $CO_2$ readings lag behind those of the Northern Hemisphere because the majority of population-based $CO_2$ emissions are located in the Northern Hemisphere.*

**Handout 2 ▸ P.1**

# Exploring Earth's History and Understanding Climate Change

**Directions for the Webquest:**

Using the first link below, work through the slides and videos in the interactive PowerPoint presentation titled "Paleoclimate — A History of Change." Take notes as you move through the information.

Howard Hughes Medical Institute (HHMI) — Paleoclimate — A History of Change
http://media.hhmi.org/biointeractive/click/paleoclimate/

When you have finished, explore the two remaining sites below to understand the complexities of climate change.

NASA
http://climate.nasa.gov/evidence/

HHMI – Geologic Carbon Cycle
http://www.hhmi.org/biointeractive/geologic-carbon-cycle

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Use your research to answer the following questions:

**1.** How has the Earth's climate changed?

**2.** How far back can scientists track the changes in climate?

**3.** What causes climate change?

Handout 2 ▸ P.2

# Exploring Earth's History and Understanding Climate Change

**4.** What are greenhouse gases? Name examples of greenhouse gases. How does each contribute to climate change?

**5.** List and explain as many sources as possible of greenhouse gases.

**6.** How do humans contribute to climate change?

**7.** How long have humans been affecting Earth's climate?

**8.** List and explain at least five things you can do to reduce greenhouse gas emissions.

**Teacher Resource**
**2 ▸ P. 1**

# Answer Sheet for Handout 2

*Below are possible responses. Please keep in mind that there is more information and detail to explore with climate change science*

**1.** How has the Earth's climate changed?

*Over time, Earth's climate has changed drastically. Earth's climate is a complex system controlled by many factors. There are two major factors that have caused most of this change. They are solar radiation and the composition of Earth's atmosphere. Both of these factors have changed the way temperature is working today. There have been times where the Earth is much warmer and cooler than it is today. Changes, like temperature, happen because the chemical composition of the atmosphere has changed over time. This results in varying the strength of the greenhouse effect. It could also be because the amount of solar radiation has varied over time.*

*The Earth's climate naturally changes very slowly and has a consistent pattern of change (warming and cooling periods). Human activities have released greenhouse gases, such as carbon dioxide. As a result, the climate has rapidly changed and is continuing to do so at rates that have never been reached before.*

**2.** How far back can scientists track the changes in climate?

*Scientists have found that the climate has changed over the past 70 million years. Scientists can track the natural warming and cooling patterns on Earth by examining the relative amounts of two oxygen isotopes. They measure the abundance of the two isotopes in the calcium carbonate shells of marine creatures that are found in ocean sediments. Here is a link to a good video that explains the science behind this method of tracking the different ice ages and interglacial periods:* https://www.youtube.com/watch?v=YfRDNyB1XOY

**3.** What causes climate change?

*There are two major factors that have caused most of climate change: solar radiation and the composition of Earth's atmosphere. Both of these factors have changed the way temperature is working today.*

*Because of variations in solar energy, ice ages have waxed and waned for the past million years. Small changes in Earth's orbit around the sun also affect the amount and distribution of solar energy striking the planet.*

*Atmospheric composition affects climate through the concentration of greenhouse gases, including carbon dioxide, methane, and water vapor.* $CO_2$ *stays in the atmosphere for a long time, and the concentration varies significantly over time, resulting in changes of temperature.*

Teacher Resource
2 ▸ P.2

# Answer Sheet for Handout 2

**4.** What are greenhouse gases? Name examples of greenhouse gases. How does each contribute to climate change?

*Greenhouse gases are in the atmosphere, and they absorb and emit radiant energy. Greenhouse gases absorb and emit in the thermal infrared range. This process results in the cause of the greenhouse effect.*

*In Earth's atmosphere, the greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide, and ozone. Water vapor is a more short-term gas and only lasts a few weeks, and carbon and methane last a long time. Without greenhouse gases, the average temperature of Earth's surface would be about 0 °F. Greenhouse gases warm the Earth by absorbing energy and slowing the rate at which the energy escapes to space. According to the United States Environmental Protection Agency (EPA) "they act like a blanket insulating the Earth."*

**5.** List and explain as many sources as possible of greenhouse gases.

*Water vapor, carbon dioxide, methane, and nitrous oxide are greenhouse gases. A greenhouse gas is any gas that contributes to the greenhouse effect by absorbing infrared radiation; for example, carbon dioxide and chlorofluorocarbons are greenhouse gases. Each greenhouse gas is different. Water vapor is the most abundant greenhouse gas.*

*Water vapor increases as the Earth's atmosphere gets warmer. When the Earth's atmosphere gets warmer, the possibility of clouds and precipitation also increases, resulting in some of the most important feedback mechanisms to the greenhouse effect.*

*Carbon dioxide is released through natural processes like "respiration and volcano eruptions and through human activities such as deforestation, land use changes, and burning fossil fuels." Because of humans' increase in the amount of* $CO_2$*, it is the most important long-lived force in climate change.*

*Methane is a hydrocarbon gas and is produced through both natural sources and human activities. This includes decomposition of wastes in landfills, agriculture, and especially rice cultivation, as well as ruminant digestion and manure management associated with domestic livestock. Methane is a far more active greenhouse gas than carbon dioxide.*

*Nitrous oxide is a powerful greenhouse gas. It is produced by soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production, and biomass burning.*

Teacher Resource
2 ▸ p.3

# Answer Sheet for Handout 2

**6.** How do humans contribute to climate change?

*See responses above. Scientists have high confidence that global temperatures will continue to rise for decades to come because of the greenhouse gases that are produced by human activities. According to NASA, "The planet's average surface temperature has risen about 2.0 degrees Fahrenheit since the late 19th century." This change was largely driven by increased carbon dioxide produced by humans and other human-made emissions into the atmosphere. Greenhouse gases in the atmosphere today are the highest the world has experienced in the past 650,000 years. Carbon dioxide enters the atmosphere through burning fossil fuels (coal, natural gas, and oil), solid waste, trees, and wood products.*

**7.** How long have humans been affecting Earth's climate?

*Changes in Earth's climate are extremely likely to be a result of human activity since the mid-20th century and "proceeding at a rate that is unprecedented over decades to millennia" according to NASA. In the United States, greenhouse gas emissions caused by human activities increased by 7 percent from 1990 to 2014. Electricity generation is the largest source of greenhouse gas emissions in the United States, followed by transportation.*

**8.** List and explain at least five things you can do to reduce greenhouse emissions.

- ***a.*** *Buy food and other products with less packaging that will end up in landfills because this will only contribute to the building of greenhouse gases (recycle!).*
- ***b.*** *Reduce heating and air conditioning in your home because it will result in less burning of fossil fuels that are a big source of $CO_2$.*
- ***c.*** *Drive less because your car gives off pollution ($CO_2$).*
- ***d.*** *Plant trees because they take in $CO_2$ and release oxygen as a result of photosynthesis.*
- ***e.*** *Turn off lights when you aren't using them because they generate heat and take energy to keep on. This energy comes from the burning of fossil fuels.*

# Handout 3 ▸ P.1 What Is Your Ecological Footprint?

**Part 1:**

Explore the link below to learn about an ecological footprint.

http://www.footprintnetwork.org/our-work/ecological-footprint/

Answer the questions below.

**1.** Describe the concept of an ecological footprint. What is it?

**2.** Explain the types of information needed to calculate an ecological footprint.

**Part 2:**

Now calculate your own ecological footprint by going to the following URL.
Answer the questions below once you have finished.

http://www.footprintcalculator.org/

**3.** What are the results of your personal ecological footprint?

**4.** How many Earths are you currently using? Please explain what this means.

# Handout 3 ▸ P.2 What Is Your Ecological Footprint?

**5.** Are you surprised by your ecological footprint results? Please explain why or why not.

**6.** What is the average number of Earths currently in use by this class?

**7.** How does the class average compare with the ecological footprint of the United States?

**8.** Based on the data provided on the Global Footprint Network Website at http://data.footprintnetwork.org/#/, how does the ecological footprint of the United States compare with that of other countries in the world?

**9.** List and explain four solutions or changes from the website that you could make to reduce your ecological footprint.

# Teacher Resource 3 Answer Sheet for Handout 3

**1.** Describe the concept of an ecological footprint. What is it?

*An ecological footprint accounting measures the demand on and supply of nature. On the demand side, the ecological footprint measures the ecological assets that a given population requires to produce the natural resources it consumes (including plant-based food and fiber products, livestock and fish products, timber and other forest products, space for urban infrastructure) and to absorb its waste, especially carbon emissions. The ecological footprint tracks the use of six categories of productive surface areas: cropland, grazing land, fishing grounds, built-up land, forest area, and carbon demand on land. On the supply side, a city, state, or nation's biocapacity represents the productivity of its ecological assets (including cropland, grazing land, forest land, fishing grounds, and built-up land). These areas, especially if left unharvested, can also absorb much of the waste we generate, especially our carbon emissions.*

**2.** Explain the types of information needed to calculate an ecological footprint.

*Refer to information in Question #1 above and the website for more information.*

**3.** What are the results of your personal ecological footprint?

*Answers will vary.*

**4.** How many Earths are you currently using? Please explain what this means.

*Answers will vary.*

**5.** Are you surprised by your ecological footprint results? Please explain why or why not.

*Answers will vary.*

**6.** What is the average number of Earths currently in use by this class?

*Have students list their results on the board and work as a group to calculate the average.*

**7.** How does the class average compare with the ecological footprint of the United States?

*Currently, the United States on average has an ecological footprint of 5 Earths.*

**8.** Based on the data provided on the Global Footprint Network Website at http://data.footprintnetwork.org/#/, how does the ecological footprint of the United States compare with that of other countries in the world?

*Have students explore the different data sets and measurements in this link. You could have them report on a country or region they choose, or you could have groups explore each continent/region and report to the class.*

**9.** List and explain four solutions or changes from the website that you could make to reduce your ecological footprint.

*Students are able to click on the "Explore Solutions" tab after they complete their ecological footprint. The solutions are divided into the following categories: City, Energy, Food, Population. Have students explore the information and report one or two interesting facts they learned.*

Handout 4 ▸ P.1

# Climate Change Activism Project Proposal

**In what area of our community/country should we make important changes?** (For example, food, transportation, electricity, clothing, housing, etc.)

**How will you share your information related to your topic? What format will you use to effectively connect with people?** (For example, social media, flyers, magazines, billboards, signs, soapbox speeches, YouTube video, music/song writing, performance, marches, protest signs, etc.)

**What are five sources of information you might use to educate yourself and others?**

**Handout 4 ▸ P.2**

# Climate Change Activism Project Proposal

**What are five examples of evidence/information you might share with others?**

**How will you actively create change? What are you doing personally to reduce your carbon footprint? What are you doing to influence societal changes?** (For example, responsible practices such as being efficient, ethical consumption, influencing public policy, supporting renewable energy, time/labor donation, voting or political advocacy, collection drives)

**Additional educational/project requirements from your teacher:**

# Climate Change: Student Activism Project

At the heart of human history is understanding how changes in society can be accomplished. Based on what you've seen in the film and what you've already learned in class, design a campaign to inform others about global climate change and participate in bringing change to our society. Change starts with us, but it can also include imploring others to do the same on a larger scale. In this project, you'll have to the chance to do both.

To be successful you must complete three parts:

1. Project Proposal
2. Awareness Campaign
3. Action Campaign

### Step 1

Climate Change Activism Project Proposal (See **Handout 4**.)

### Step 2:

Create an **AWARENESS CAMPAIGN** that spreads information about how your topic affects global climate change so that people are aware of both the problem and possible solutions to it.

a. You must share important information about climate change with your target demographic beyond the classroom. Consider these examples as possible formats for your campaign: social media, flyers, signs, billboards, magazines, soapbox speeches, YouTube video, music/song writing, performance, marches, protest signs, etc.

b. You must explain the problem and provide evidence of its effect on global climate change. Your topic will potentially concern these aspects of climate change:

   Global temperature rise
   Warming oceans
   Shrinking ice sheets
   Glacial retreat
   Decreased snow cover
   Sea level rise
   Declining Arctic sea ice
   Extreme events
   Ocean acidification

c. You must provide at least two potential solutions to the problem (e.g., responsible practices, such as saving electricity, time/labor donation, voting or political advocacy, collection drives, grant writing, protests).

Handout 5 ▸ p.2

# Climate Change: Student Activism Project

### Step 3

**TAKE ACTION.** Document practices that make a difference through an Action Campaign. What can you and others do about global climate change at home or in our society?

a. What are you doing personally to reduce your carbon footprint? Choose the best, most appropriate methods that will, even on a small level, solve the problem. (For example, responsible practices such as being efficient, ethical consumption, etc.)

b. What are you doing to influence changes that go beyond yourself? (For example, influencing public policy, supporting renewable energy, time/labor donation, voting or political advocacy, writing a letter to a business or politician who has the power to effect change.)

National Geographic
1145 17th Street NW
Washington, DC 20036
www.natgeo.com

Journeys in Film
PO Box 65357
Albuquerque, NM 87193
www.journeysinfilm.org