Shenandoah Salamander: Climate Change Casualty or Survivor?

Program Name: Shenandoah Salamander: Climate Change Casualty or Survivor?

Suggested Grade Level: 9th – 12th Life Science, Environmental Science

Maximum Group Size: 25 students (plus chaperones)

Introduction
This lesson is a *Landforms and Life Forms* unit of the **Exploring Earth Science in Shenandoah National Park** curriculum. Pre-visit activities introduce students to relevant concepts in preparation for their park visit. On-site activity descriptions and worksheets are included for the park field trip. Post-visit activities are included to be completed after returning to school so that students can apply what they learned to their home environment.

Overview
Climate change can be defined as any significant change in the climate lasting for decades or longer. Climate patterns can vary naturally, but today's climate changes are being accelerated by human activity. Although scientists cannot yet predict with certainty what the long-term impacts from climate change will be, there is ample evidence that climate change effects are already being felt within national parks. Students will research climate change and the potential impact on two salamander species found in Shenandoah National Park, the endangered Shenandoah salamander and the more common red-backed salamander. Students will conduct field research on the red-backed salamander to compare the two species' habitat requirements and determine if climate change and competition for habitat are impacting the survival of the Shenandoah and red-backed salamanders. Students will interact with real data and online simulations to understand the relationship between greenhouse gases in the atmosphere and global temperature patterns. Finally, they will explore how their actions contribute to global climate change and create a social media campaign to inform others about global climate change and its potential impacts at Shenandoah National Park and beyond.

Unit Objectives
Following the park experience and classroom activities, the students will be able to
1. define climate change and list examples of natural and human-influenced contributors to climate change;
2. conduct a salamander population study to determine habitat preferences and favorable environmental conditions for salamanders in Shenandoah National Park;
3. analyze data collected in the field to compare location preferences between the red-backed and the Shenandoah salamanders;
4. assess/predict the potential impact of climate change and species competition on the survival of the Shenandoah and red-backed salamanders;
5. explain the "greenhouse effect" and articulate the connection between atmospheric gases and global temperature;
6. determine ways people can reduce their contributions to climate change;
7. create a persuasive media campaign to educate others on the impacts of climate change and how people can reduce their carbon footprint.

Synopsis of Lessons

Lesson 1 – Introducing Climate Change and Salamander Research in Shenandoah National Park
Students will be introduced to the concept of climate change and will learn about human causes and environmental impacts. This knowledge will then be applied to Shenandoah National Park, specifically looking at how the endangered Shenandoah salamander may be affected by a changing climate. Finally, students will learn the biological differences between the Shenandoah salamander and the more common red-backed salamander.

Lesson 2 – Sampling for the Red-backed Salamander
Students will participate in a ranger-led program in which they set up and explore a series of transects to look for the red-backed salamander.

Lesson 3 – Analyzing Data and Drawing Conclusions
Students will analyze the data they collected from the ranger-led program and draw conclusions about physical and biological preferences of the red-backed salamander. They will then compare the preferences of the red-backed salamander to the Shenandoah salamander.

Lesson 4 – Introduction to Climate Change Science
Students will utilize online simulations to visualize the greenhouse effect. They will then compare their conclusions from the simulations with data collected from NOAA and NASA scientists about current temperature and carbon dioxide trends. Finally, students will interpret a graphic to understand the pathways in which carbon dioxide enters and exits the atmosphere.

Lesson 5 – Individual Impact on the Climate and Climate Change Communication
Students will create a social media campaign to disseminate information about climate change in Shenandoah National Park. They will also learn about carbon footprint and make a pledge on how they can reduce their personal carbon emissions.

Virginia Science Standards of Learning

All Grade Levels

Scientific and Engineering Practices

The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
b) planning and carrying out investigations
c) interpreting, analyzing, and evaluating data
d) constructing and critiquing conclusions and explanations
e) developing and using models
f) obtaining, evaluating, and communicating information

Life Science

LS.8 The student will investigate and understand that ecosystems, communities, populations, and organisms are dynamic and change over time. Key ideas include

a) organisms respond to daily, seasonal, and long-term changes;
b) changes in the environment may increase or decrease population size; and
c) large-scale changes such as eutrophication, climate changes, and catastrophic disturbances affect ecosystems.

LS.9 The student will investigate and understand that relationships exist between ecosystem dynamics and human activity. Key ideas include

a) changes in habitat can disturb populations;
b) disruptions in ecosystems can change species competition; and
c) variations in biotic and abiotic factors can change ecosystems.

Earth Science

ES.6 The student will investigate and understand that resource use is complex. Key ideas include

a) global resource use has environmental liabilities and benefits;
b) availability, renewal rates, and economic effects are considerations when using resources;
c) use of Virginia resources has an effect on the environment and the economy; and
d) all energy sources have environmental and economic effects.

ES.11 The student will investigate and understand that the atmosphere is a complex, dynamic system and is subject to long-and short-term variations. Key ideas include

c) natural events and human actions may stress atmospheric regulation mechanisms; and
d) human actions, including economic and policy decisions, affect the atmosphere.

ES.12 The student will investigate and understand that Earth's weather and climate are the result of the interaction of the sun's energy with the atmosphere, oceans, and the land. Key ideas include

a) weather involves the reflection, absorption, storage, and redistribution of energy over short to medium time spans;

c) extreme imbalances in energy distribution in the oceans, atmosphere, and the land may lead to severe weather conditions;
e) changes in the atmosphere and the oceans due to natural and human activity affect global climate.

Biology

BIO.8 The student will investigate and understand that there are dynamic equilibria within populations, communities, and ecosystems. Key ideas include
a) interactions within and among populations include carrying capacities, limiting factors, and growth curves;
d) natural events and human activities influence local and global ecosystems and may affect the flora and fauna of Virginia.

Mathematics

AFDA.8 The student will design and conduct an experiment/survey. Key concepts include;
a) sample size;
b) sampling technique;
c) data collection;
d) data analysis and reporting.

English

9.2 The student will produce, analyze, and evaluate media messages.
9.6 The student will write in a variety of forms to include expository, persuasive, reflective, and analytic with an emphasis on persuasion and analysis.
9.8 The student will find, evaluate, and select credible resources to create a research product.

National Science Education Standards
As a result of their activities in grades 9-12, all students should develop an understanding of:

Science as inquiry standard - Content Standard A
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Life science standard - Content Standard C
- Behavior of organisms

Earth and space science standard - Content Standard D
- Energy in the earth system

Science and technology standard - Content Standard E
- Understanding about science and technology

Science in social and personal perspectives - Content Standard F
- Population growth
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Nature and history of science standard - Content Standard G
- Science as a human endeavor
- Nature of scientific knowledge

Unit Location Information
The in-park portion of this curriculum must be led by a ranger from Shenandoah National Park. Call the Education Office to schedule your field trip and arrange for a ranger to guide the class through the on-site lesson.

Contact Information:
Shenandoah National Park Education Office
3655 U.S. Hwy 211 East
Luray, VA 22835
540-999-3500 ext. 3489
Email: shen_education@nps.gov

Shenandoah National Park Location:
Byrd Visitor Center, Big Meadows transect locations

Mile: 51 for Byrd Visitor Center and Big Meadows

Site Capacity: 25 students maximum, divided into 4 groups at the site location

Parking Lot Size: Paved parking lot at Byrd Visitor Center will accommodate a school bus

Restroom Facilities: Byrd Visitor Center (Milepost 51)

Trail Information: Easy trail with little elevation change. Some off-trail travel is required at this site. Please take care to protect the plant and animal habitats located off the trail.

Site Constraints: Because of the narrow trail and off-trail activities, group size should not exceed 25 students.

Accessibility: Byrd Visitor Center is accessible. The on-site activities for this module are not accessible to wheelchairs.

Safety Concerns: Be cautious of the traffic on Skyline Drive. Other hazards to be aware of are poison ivy, snakes, and ticks.

Ecological Considerations: The Big Meadows area is popular and is subject to heavy human impacts. Please stay single file when hiking on the trails to reduce resource damage. Follow the park rules and regulations by not feeding the wildlife, disturbing the flora and fauna, or removing samples of the natural and cultural resources.

Extra care must be taken when dealing with live animals. Salamanders must only be handled using the technique described in this curriculum guide. Salamanders must be returned to the area where they are found, and all rocks, logs, and leaf litter must be placed back where they were originally. *Do not* place cover material such as rocks or logs directly on top of salamanders.

Pre/Post Test

1. Which of the following is an endangered species of salamander?
   - ☐ Spotted salamander
   - ☐ Northern dusky salamander
   - ☐ Red-backed salamander
   - ☐ Shenandoah salamander
2. Where is an adult salamander likely to be found?
   - ☐ In or on dry soil
   - ☐ High up in trees
   - ☐ In or on moist soil
   - ☐ In the middle of lakes
3. What does it mean when a species is endangered?
   - ☐ Humans have decided to hunt them for food or protect other species.
   - ☐ The number of animals is shrinking and the species could completely die out.
   - ☐ The species has completed died out. There are no more of these animals in the world.
   - ☐ The animals are starting cause problems for humans so we must limit the number.
4. If a species has a 50-70% population decline it would be classified as ____.
   - ☐ extinct in the wild
   - ☐ endangered
   - ☐ threatened
   - ☐ a species not needing concern
5. A microclimate is an area
   - ☐ of uniform climate in a small site or habitat.
   - ☐ containing only one variety of vegetation.
   - ☐ of land located under tall vegetation.
6. Which of the following statements correctly describes weather and climate?
   - ☐ Weather refers to the more current conditions, while climate refers to the long-term conditions.
   - ☐ Weather and climate are the same.
   - ☐ Climate refers to the more current conditions, while weather refers to the long-term conditions.
7. What do greenhouse gases do to atmospheric temperatures?
   - ☐ Decrease the temperatures.
   - ☐ Increase the temperatures.
   - ☐ They do not change the temperatures.
8. Which of the following is NOT a greenhouse gas?
   - ☐ Oxygen
   - ☐ Water vapor
   - ☐ Carbon dioxide
   - ☐ Methane
9. Which of the following activities releases carbon dioxide directly into the atmosphere?
   - ☐ Failing to recycle.
   - ☐ Watering the lawn during a draught.
   - ☐ Littering.
   - ☐ Burning fossil fuels.
10. In the space below, write a short description of what a carbon footprint is.

Pre/Post Test – Answer Key

1. Which of the following is an endangered species of salamander?
   - ☐ Spotted salamander
   - ☐ Northern dusky salamander
   - ☐ Red-backed salamander
   - ✓ Shenandoah salamander
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   - ☐ Littering.
   - ✓ Burning fossil fuels.
10. In the space below, write a short description of what a carbon footprint is.
    - The amount of carbon dioxide emitted due to the use of fossil fuels by an individual.

Lesson 1: Introducing Climate Change and Salamander Research in Shenandoah National Park
Pre-visit Lesson – Teacher Sheet

Introduction:
The mission of the National Park Service is to preserve and protect natural and cultural resources and leave them *unimpaired* for the enjoyment of future generations. This lesson will help students to understand how climate change and competition with the red-backed salamander could impact the survival of the endangered Shenandoah salamander.

Instructional Objectives:
1. Students will discuss climate change and how the impacts of climate change may be felt locally.
2. Students will understand the plight of the Shenandoah salamander.
3. Students will be able to identify the differences between the Shenandoah salamander and the red-backed salamander.

Previous Knowledge:
Ability to search for quality information online.

Time to Complete: 1-2 class periods

Materials Needed:
Computer and internet access for research
Ability to play internet videos for whole class (computer with projector and speakers)
Shenandoah National Park climate change and salamander videos (see the References and resources)
Student field guide (attached at the end of Lesson 1)

Procedure

A. Shenandoah National Park Needs Your Help

Refer to the attached Teacher Pages: Background Information at the end of Lesson 1. Tell the students, *"Shenandoah National Park researchers need help in their study of the Shenandoah salamander (Plethodon shenandoah) which lives nowhere else on the planet except a few rocky mountaintops in the park. It is a federally endangered animal species found in the park. It is suspected that competition with red-backed salamanders and the impacts of climate change could cause a serious decline in the population of the Shenandoah salamander. Park managers are responsible for the preservation and protection of species and resources for future generations. The need for the scientific data is critical."*

Ask students to think for a moment about what they know about Shenandoah National Park, climate change, and the endangered Shenandoah salamander. Have students discuss their thoughts with a partner and then allow students to share their answers with the class. While students are sharing answers they can fill out the "What I have heard, read, seen, believe" and

"What I want to research at home" column of the Progression of Understanding sheet in the student field guide.

B. Climate change and Shenandoah salamander videos

Using the park videos (links are provided on the References and resources page), guide the students in a discussion of what they should find out to prepare for their research and field study.

1. Watch the climate change video for an overview of climate change.
2. Watch the Shenandoah salamander video, pausing at the listed intervals to allow time for discussion.

Segment 1, Time 0 – 2:13, Pause

Discussion Questions:

- Why is the Shenandoah salamander a federally endangered species?
  Rarity, restricted range
- What makes microclimates or "islands in the sky" different?
  They support unique ecosystems that are isolated from each other, and have species that are not found elsewhere in Virginia – red spruce, balsam fir, etc.
- Describe the habitat of the Shenandoah salamander and its needs.
  Cooler temperatures and higher humidity, rocks and other cover to protect it from the sun's heat and drying effect, as well as predators from above like birds.
- How do we know the earth's temperature is changing?
  Climate models show a trend for future temperature increase.
- What is causing unprecedented climate change?
  Human activities are causing more greenhouse gas emissions.

Segment 2, Time 2:13 – 4:10, Pause

Discussion Questions:

- What will be the impact of climate change on the Blue Ridge Mountains in Shenandoah National Park? (*rhetorical question posed*)
- How will a changing climate alter the microclimates on the summits of Shenandoah's highest peaks? (*rhetorical question posed*)
- How will a changing climate affect the limited range where the Shenandoah salamander lives? (*rhetorical question posed*)
- Why has the Shenandoah salamander retreated up the mountainside causing a more isolated, restricted range?
  Cooler temperatures, competition from the red-backed salamander
- What other factors are involved in putting pressure on the survival of the Shenandoah salamander besides climate change?
  Competition for habitat from the red-backed salamander, more isolated habitats
- What conditions are projected due to climate change?
  Warmer temperatures, extended periods of drought, more violent storms, increased wildfires
- How could climate change be a factor in the population decrease of the Shenandoah salamander?
  Increased temperatures and drier conditions in already small and isolated habitats

- What are the options for the future of the Shenandoah salamander?
  Adapt? Migrate? Extinction?

Tell the students that scientists conducted research to determine the environmental conditions in high elevation habitats necessary for the survival of salamanders.

Segment 3, Time 4:11 – 5:16, Pause

Discussion Questions:

- Who are the partners in this research and what are they studying?
  Shenandoah National Park, University of Virginia, US Geological Survey, Smithsonian Institution
- What type of climate data is being collected and analyzed to predict the future of the climate in Shenandoah National Park?
  Temperature and humidity data from over the last 75 years at Big Meadows weather station in Shenandoah National Park and temperature sensors ("hobos") on Hawksbill Mountain – they will create models of future climate change by comparing the two data sets with potential future greenhouse gas emissions

Tell the students: *"When we go to Shenandoah National Park, we will not be able to sample the Shenandoah salamander due to its rare and endangered status. Instead, we will be performing field investigations which duplicate the techniques that the researchers used in their study on the red-backed salamander. You will search for salamanders, measure them, and collect environmental data (air temperature, wind speed, humidity, soil moisture and pH). Here is what researchers have been doing in Shenandoah National Park on the Shenandoah salamander so far."*

Segment 4, Time 5:17 – 6:55, Pause

Discussion Questions:

- What type of research is being done on the Shenandoah salamander in Shenandoah National Park?
  Mapping the range of the Shenandoah salamander, studying the impacts of temperature and moisture change in these habitats.
- What is the purpose of the project?
  It will provide biological information on the Shenandoah salamander to help the National Park Service make good decisions about preserving and conserving this species.
- How are the habitat requirements of the Shenandoah salamander (*Plethodon shenandoah*) and the red-backed salamander (*Plethodon cinereus*) similar/different?
  Both like cool, humid areas, leaf litter, a little soil, and invertebrates to eat, but the red-backed will occupy the best sites and will exclude the Shenandoah salamander. Within high elevation areas, the Shenandoah salamander seems to be able to tolerate drier habitats with mostly rock and less leaf litter and soil, which might lead to slightly warmer conditions.
- What are the two abiotic climate factors being studied that might be affecting the Shenandoah salamander?
  Increased temperature and decreased humidity
- What biotic factors are being studied that might affect the Shenandoah salamander?
  Competition with red-backed salamander

Segment 5, Time: 6:56 – end

Discussion Questions:

- What does the researcher mean by "looming stress of climate change"?
  Climate change could fundamentally change the abiotic conditions in a habitat, which in turn will cause shifts in the biota of the habitat – migration, phenology changes, population changes/crashes, etc.
- What might be your idea for the best strategy for the protection and preservation of the Shenandoah salamander? (*open-ended discussion*)
- What can people do now to protect this species for future generations? (*open-ended discussion*)

C. Screen Time! Background Research

Explain to the students that they will be using **primary source** resources to do their research on salamanders and climate change. Have them complete the attached Field Guide to Virginia Amphibians graphic organizer to differentiate between the Shenandoah and red-backed salamanders. Give a brief review of using only credible websites and avoiding plagiarism. A list of possible websites to use is available on the References and resources page.

Tell the students: *"Now that we know about the park's research and the biological characteristics of each of the two salamanders, we need to prepare for our field experience. In partners, compare and contrast the red-backed salamander and the Shenandoah salamander while completing the double bubble graphic organizer.*

D. Practice setting up a transect and sampling for the red-backed salamander

Materials Needed:

- artificial salamanders (or small photos)
- various items to conceal artificial salamanders
- zip-top plastic baggies
- 4 reel-type 10 meter measuring tapes
- flagging tape or small marker flags
- hand sanitizer (60-70% ethyl alcohol) - (optional)
- 4 portable weather stations (optional)
- 2 soil moisture and pH meters (optional)
- field data sheets
- clipboards
- pencils
- GPS device (optional)

Explain that the salamander researchers used a transect sampling technique. Transect techniques involve sampling along a line. There are many variations, but most involve stopping at intervals along that line and collecting data, i.e., searching under rocks, logs, and leaf litter for salamanders. Data is recorded at every location in which a salamander is found. Even if no salamanders are found along the transect, temperature, humidity, and soil readings are still recorded. The students will practice this sampling technique before going into the field.

Conduct Practice Transect

To practice the sampling procedure and handling technique, randomly distribute artificial salamanders in an open area inside or on the school grounds. Conceal the salamanders under pails, plates, or other items that represent rocks/logs/leaves.

Divide students into four research teams. Review the data collection sheet. Within each team, assign tasks for searching, measuring, and recording data. Rotate assignments if desired. Students will lay out a transect line, search for "salamanders", take measurements, and record data while practicing proper searching and handling techniques.

Have the research teams develop a hypothesis statement on the habitat requirements of the red-backed salamander. What conditions do they expect to find and what environmental conditions would impact its survival? Remember the hypothesis should be an 'If……, then……' statement.

Transect Sampling Procedure
1. Select a location where the transect line will cross several potential salamander hiding places.
2. Survey the study area for any potential safety concerns such as poison ivy, stinging nettle, ant/insect nests, other animals such as snakes, or broken overhanging limbs. Look carefully above and around each rock, log, or leaf litter that you will search under.
3. From a starting point, decide a compass direction line using a GPS unit. Record the direction and measure a 10 meter line in that direction for the study transect line.
4. Find and record the latitude/longitude coordinates of starting point using a GPS.
5. Keep the measuring tape on the ground to act as a guide. Mark each end of transect line with flagging tape or marker flags.
6. Sanitize your hands to prevent contamination of the study site or organisms.
7. Search for salamanders within one-half meter along either side of the transect line (10 square meters).
8. Turn over rocks, logs, and leaf litter using proper the searching/handling protocol.
9. For each salamander found, measure and record required data in pencil (pen ink can run if it gets wet). Record up to 15 samples.
10. Document on the data sheet if no salamanders are found.

Salamanders must be handled with care. Provide this background information and review proper handling procedures.

An amphibian's thin, moist skin absorbs oxygen from the atmosphere. The skin can also absorb anything else that it comes into contact with. If you have perfume, insecticide, hand lotion, or even soap residue on your hands when you handle the salamander, it will absorb whatever is on your skin, perhaps with fatal results. When you handle a salamander, you may also transfer diseases to the animal from your hands. Therefore, use an appropriate 60-70% alcohol sanitizer on your hands prior to sampling in any salamander habitat.

In addition, compared to the ambient temperature of a salamander or frog, your hands are hot. The heat from your clean hands and the stress of being handled can actually cause unnecessary stress or death to the salamander. Over-handling can rub off the amphibian's protective mucous coating on the skin. This mucous provides anti-bacterial and anti-fungal protection to the amphibian to prevent infection and illness. Therefore, direct contact with the salamanders' skin should be avoided. You will be using re-sealable plastic baggies to handle the salamanders and take measurements.

How to Search For and Handle Salamanders
a. Sanitize your hands to prevent contamination of the study site or organisms.
b. Organize the transect group into pairs. One partner will search on one side of the transect line, and the other partner will search on the other side of the transect line. Try to stay together as much as possible, as the pair will need to work together when a salamander is found.
c. Search under all cover objects by gently and slowly pulling the rock, log, or leaf litter TOWARDS YOU with both hands. This will provide an escape route for animals that might be there and will be a safety barrier for you. Note: you may have to move your body in order to lift rocks and logs towards you.
d. As you slowly pull the rock/log/leaves towards you, quickly look under it. Gently place the rock, etc. to the side.
e. When a salamander is found, have your partner turn the plastic baggie inside out and place his/her hand inside. Gently scoop the salamander into the baggie and invert to seal the bag and contain the salamander. Avoid holding it in your hands very long as your hot hand may be uncomfortable.
f. After the salamander has been placed in the baggie, replace the rock/log/leaves.
g. Record the salamander's location in meters along your transect from the starting point.
h. Hold the bag by the zipper top. Gently place the plastic bag on a flat surface and quickly measure the salamander's length in cm. Record on the data sheet.
i. Observe the salamander for coloring, unique features, and behavior. Record observations on the sheet.
j. After measuring and observing the salamander, open the bag and release it next to the rock/log/leaves that you have replaced without holding it in your hand. It will most likely scoot safely under the cover avoiding light and seeking dampness.

Teacher Pages: Background Information

Climate Change

Climate change is any significant change in the climate lasting for decades or longer. Climate patterns (e.g. temperature, rain, snow) can vary naturally, but modern climate changes are accelerated by human activity. Although scientists cannot yet predict with certainty what the long-term impacts from climate change will be, there is ample evidence of climate change effects already being felt within national parks.

Major greenhouse gases - carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and water vapor (H_2O) - trap some of the sun's heat in the atmosphere. At natural levels, this is enough heat to keep earth from freezing and helps to sustain life as we know it. Natural sources of greenhouse gases include plant respiration, volcanic eruptions, and natural decomposition of living things.

Human activities, such as burning fossil fuels (oil, coal, and natural gas), increase greenhouse gas levels. These extra gases trap even more heat, resulting in global warming and unprecedented rates of climate change. The total amount of greenhouse gas emissions caused by a person, household, event, or organization is called its "carbon footprint". This value can be calculated to help understand fossil fuel use and to help make personal choices to reduce the amount of carbon released into the environment.

Global warming is an increase of temperatures in the atmosphere and oceans around the world. Greenhouse gases are a major contributor to increasing global temperatures. This warming can change global climate factors such as temperature, humidity, rainfall, snowfall, and storm frequency and intensity.

Impacts on Shenandoah National Park

Increasing temperatures due to climate change can impose greater stress on species residing in the *microclimates* of higher elevations. Worldwide, these species are at risk of extinction. Many of these higher elevation habitats that support unique ecosystems are located within the boundaries of Shenandoah National Park. Local scientists are predicting dramatic alterations in temperature and moisture gradients in the Appalachian Mountains in the future. One such species at risk is the endemic Shenandoah salamander (*Plethodon shenandoah).*

Salamanders are amphibians like frogs and toads. Most need water or moisture in which to reproduce. They live in a wide variety of habitats from swift-moving mountain streams to moist forests. In many habitats they are the most abundant vertebrates. Of the more than 400 species of salamanders found worldwide, 130 to 150 live in North America. Over 40 percent of these are considered to be at risk. The greatest diversity of salamanders in the world is found in the Southeastern United States. Currently, 11 species are on the federal endangered or threatened species list in the United States.

Salamander habitat is being destroyed, modified, and fragmented, seriously diminishing the diversity and number of salamanders in the United States and around the world. Climate change is

another factor that could impact their survival. Although these secretive creatures are unknown to many people, they are an important part of our natural world and are in serious need of our protection.

Shenandoah National Park serves as a refuge for many species of animals otherwise pressured by human activities such as development and other land uses. There are over 200 resident and transient bird species, over 50 mammal species, 51 reptile and amphibian species, and over 35 fish species found in the park. Shenandoah is home to 14 species of salamanders. The Shenandoah salamander (*Plethodon shenandoah*) lives nowhere else on the planet except a few rocky mountaintops in the park and is a federally endangered animal species.

Across the country, scientists are studying potential impacts of a warming climate. Shenandoah National Park has collaborated with the Smithsonian Institution, University of Virginia, and the U.S. Geological Survey to assess potential climate change impacts on its high elevation species. Research and experiments focusing on the Shenandoah salamander investigate how climate change might affect the species' use of habitat, feeding success, growth, and competition for habitat with red-backed salamanders. Additional research is being done on the two color morphs of the red-backed salamander to test the hypothesis that the "lead-backed" (unstriped morph) can withstand higher temperatures than the red-backed striped morph. This may mean that the lead-backed morph has a better chance of survival in a warmer climate. This research will help resource managers understand the habitat needs of these and other species that are highly adapted to mountaintop living and to develop strategies that will help protect these species.

Glossary

- **amphibian -** *a cold-blooded vertebrate that spends some time on land but must breed and develop into an adult in moist areas. Frogs, salamanders, and toads are amphibians*
- **carbon footprint -** *the amount of carbon dioxide (CO_2) we emit individually in any one-year period. CO_2 is produced from many sources and is the primary gas responsible for changes in our climate*
- **climate change -** *long-term alteration in global weather patterns, especially increases in temperature and storm activity. These changes can result from natural and/or human-induced processes*
- **competition -** *the interaction between organisms or species in which both organisms are harmed*
- **ectothermic -** *body temperature varies with environmental surroundings; cold-blooded*
- **endangered species -** *a species whose numbers are so few, or are declining so quickly, that the animal, plant, or other organism may soon become extinct. Endangered species are sometimes protected under national or international law*
- **endemic -** *native to or confined to a certain region*
- **endothermic –** *maintaining a constant body temperature despite changes in the temperature of the environment; warm-blooded*
- **extinction –** *condition in which a species no longer exists or is living*

- **greenhouse gases -** *any of the atmospheric gases that contribute to the greenhouse effect by absorbing infrared radiation from the sun. They include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and water vapor (H_2O). Although greenhouse gases occur naturally in the atmosphere, the substantially elevated levels especially of carbon dioxide and methane that have been observed in recent decades are directly related to human activities such as the burning of fossil fuels and deforestation*
- **habitat –** *the environment in which a plant or animal lives*
- **microclimate -** *the uniform climate in a habitat or small geographic area*
- **morph –** *natural variations in a gene, DNA sequence, or chromosome that have no adverse effects on the individual and frequently occur in the general population. The Shenandoah and red-backed salamanders have two color morphs: striped – with a reddish dorsal stripe, and unstriped or "lead-backed" - with no dorsal stripe*
- **preservation -** *the guarding of something from danger, harm, or injury*
- **protection -** *regulated and managed to achieve specific conservation objectives*

Student Field Guide for Lessons 1-4

Teachers can create a field guide for each individual student's pre-visit and post-visit activities from lessons 1 through 5. This guide should include data sheets to be completed while visiting the park. This field guide allows students to see the connections between the different activities.

Suggested contents for student field guides:

- Field guide cover page
- Climate change introduction and student definitions page
- Progression of Understanding
- Field Guide to Virginia Amphibians: Shenandoah salamander
- Field Guide to Virginia Amphibians: Red-backed salamander
- Double-bubble comparison: Shenandoah salamander and Red-backed salamander
- On-site visit data sheet: Transect Field Data Sheet
- On-site visit data sheet: Sampling Data Sheet
- Comparing Two Sites of the Shenandoah Salamander Field Study
- Social Media campaign worksheet
- Putting It All Together
- Carbon Footprint and Pledge

Field Notes

Name

Shenandoah National Park

Background Information

Climate change is any significant change in the climate lasting for decades or longer. Climate patterns (e.g. temperature, rain, snow) can vary naturally, but modern climate changes are accelerated by human activity. Although scientists cannot yet predict with certainty what the long-term impacts from climate change will be, there is ample evidence of climate change effects already being felt within national parks.

Major greenhouse gases - carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and water vapor (H_2O) - trap some of the sun's heat in the atmosphere. At natural levels, this is enough heat to keep earth from freezing and helps to sustain life as we know it. Natural sources of greenhouse gases include plant respiration, volcanic eruptions, and natural decomposition of living things.

Human activities, such as burning fossil fuels (oil, coal, and natural gas), increase greenhouse gas levels. These extra gases trap even more heat, resulting in global warming and unprecedented rates of climate change. The total amount of greenhouse gas emissions caused by a person, household, event, or organization is called its "carbon footprint". This value can be calculated to help understand fossil fuel use and to help make personal choices to reduce the amount of carbon released into the environment.

Global warming is an increase of temperatures in the atmosphere and oceans around the world. Greenhouse gases are a major contributor to increasing global temperatures. This warming can change global climate factors such as temperature, humidity, rainfall, snowfall, and storm frequency and intensity.

Student Definitions

amphibian - *a cold-blooded vertebrate that spends some time on land but must breed and develop into an adult in moist areas. Frogs, salamanders, and toads are amphibians*
carbon footprint - *the amount of carbon dioxide (CO_2) we emit individually in any one-year period. CO_2 is produced from many sources and is the primary gas responsible for changes in our climate*
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protection – *regulated and managed to achieve specific conservation objectives*

Progression of Understanding

Name: _____ Date: _____

In the first column, write what you already know about climate change and the Shenandoah salamander. In the second column, write what you want to research on your own about climate change and the Shenandoah salamander. **After** you have watched the videos and completed your lesson, write what you have learned in the third column.

What I have **heard, read, seen, believe**	What I want to **research at home**	What I **learned from this class discussion**

Field Guide to Virginia Amphibians:
Shenandoah Salamander

Scientific Name:

Size:

Habitat:

Range:

Diet:

Temperature requirements:

Moisture requirements:

General description:

Draw picture here:

Interesting facts:

Field Guide to Virginia Amphibians:

Red-backed Salamander

Scientific Name:

Size:

Habitat:

Range:

Draw picture here:

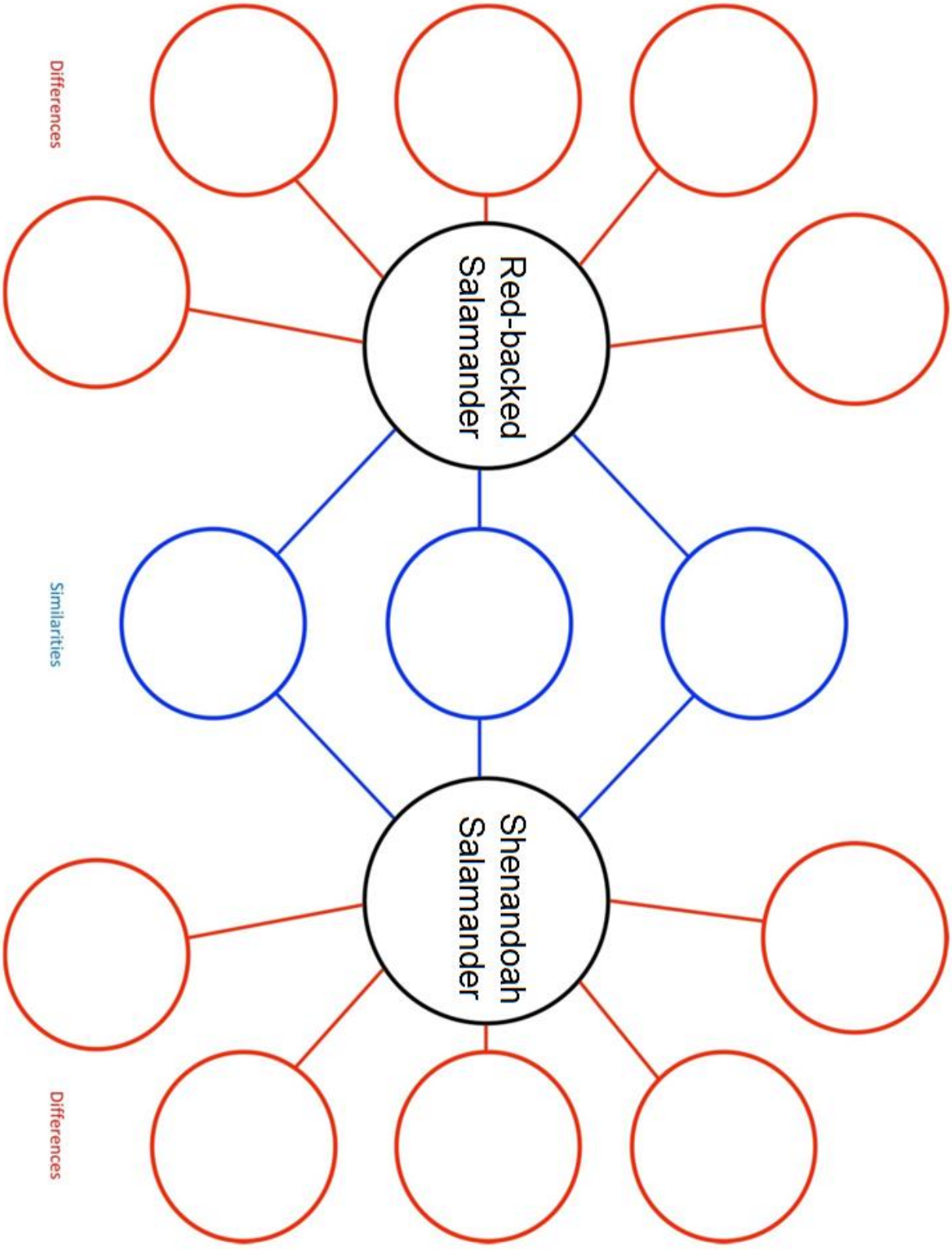
Diet:

Temperature requirements:

Moisture requirements:

General description:

Interesting facts:


Differences
Red-backed Salamander
Similarities
Shenandoah Salamander
Differences

Transect Field Data Sheet

Hypothesis:

_____

_____

Research Team: _____ Date: _____ Time: _____

Transect #: ____ Compass Direction: _____ Starting point – Latitude: _____ Longitude: _____

Wind Speed: _____ Air temperature: _____ Relative Humidity _____ Soil moisture_____ Soil pH _____

Weather (circle): Clear, partly cloudy, overcast Rain in the last 24 hours? Yes No

Materials (provided by ranger): sanitizer, measuring tape, flagging tape or marker flags, field data sheet, clipboard, pencils, zip-top plastic baggies, small metric rulers, portable weather stations, soil moisture/pH meter, GPS unit.

Transect Sampling Procedure

1. Select a location where the transect line will cross several potential salamander hiding places.
2. Survey the study area for any potential safety concerns such as poison ivy, stinging nettle, ant/insect nests, other animals such as snakes, or broken overhanging limbs. Look carefully above and around each rock, log, or leaf litter that you will search under.
3. From a starting point, decide a compass direction line using a GPS unit. Record the direction and measure a 10 meter line in that direction for the study transect line.
4. Find and record the latitude/longitude coordinates of starting point using a GPS.
5. Keep the measuring tape on the ground to act as a guide. Mark each end of transect line with flagging tape or marker flags.
6. Sanitize your hands to prevent contamination of the study site or organisms.
7. Search for salamanders within one-half meter along either side of the transect line (10 square meters).
8. Turn over rocks, logs, and leaf litter using proper the searching/handling protocol.
9. For each salamander found, measure and record required data in pencil (pen ink can run if it gets wet). Record up to 15 samples.
10. Document on the data sheet if no salamanders are found.

How to Search For and Handle Salamanders
a. Sanitize your hands to prevent contamination of the study site or organisms.
b. Organize the transect group into pairs. One partner will search on one side of the transect line, and the other partner will search on the other side of the transect line. Try to stay together as much as possible, as the pair will need to work together when a salamander is found.
c. Search under all cover objects by gently and slowly pulling the rock, log, or leaf litter TOWARDS YOU with both hands. This will provide an escape route for animals that might be there and will be a safety barrier for you. Note: you may have to move your body in order to lift rocks and logs towards you.
d. As you slowly pull the rock/log/leaves towards you, quickly look under it. Gently place the rock, etc. to the side.
e. When a salamander is found, have your partner turn the plastic baggie inside out and place his/her hand inside. Gently scoop the salamander into the baggie and invert to seal the bag and contain the salamander. Avoid holding it in your hands very long as your hot hand may be uncomfortable.
f. After the salamander has been placed in the baggie, replace the rock/log/leaves.
g. Record the salamander's location in meters along your transect from the starting point.
h. Hold the bag by the zipper top. Gently place the plastic bag on a flat surface and quickly measure the salamander's length in cm. Record on the data sheet.
i. Observe the salamander for coloring, unique features, and behavior. Record observations on the sheet.
j. After measuring and observing the salamander, open the bag and release it next to the rock/log/leaves that you have replaced without holding it in your hand. It will most likely scoot safely under the cover avoiding light and seeking dampness.

Sampling Data Sheet

Salamander caught	Salamander Location: meters from start point	Size in cm – Snout to tip of tail	Color Morph: Striped or Lead-backed?	Salamander Notes/Behavior
1st				
2nd				
3rd				
4th				
5th				
6th				
7th				
8th				
9th				
10th				
11th				
12th				
13th				
14th				
15th				

Comparing Two Sites of the Shenandoah Salamander Field Study

Site	Location	Air Temperature (^{o}C)	Wind Speed (mph)	# of Ground Cover Objects	Shenandoah salamander #	Red-backed salamander #
19	Edge of range of Shenandoah salamander	21.5	2	117	0	6
20	Historic range of Shenandoah salamander	23.8	3	86	2	0

Look at the above table from a study of the Shenandoah salamander completed in the summer of 2011 and complete the following questions.

1. Based on the number of ground cover objects listed, which site is mostly likely forested, and which site is most likely rocky terrain.

2. Which type of ground cover do you think would keep the ground cooler and moister, forested ground cover or rocky terrain?

3. The data from Site 20 was taken on one of the highest peaks in Shenandoah National Park. Why do you think it has a higher temperature than site 19?

4. If global temperatures continue to increase, which site do you think would be more impacted? What does this mean for the endangered Shenandoah salamander?

Create a Social Media Campaign

1. Give your campaign a name and a username (a shortened version of your name).
2. Draw a logo that will be your campaign's profile picture.
3. Write a mission statement that explains what your campaign will accomplish.
4. Post 10 campaign messages. Messages must be no longer than 140 characters - including hashtags! Your followers are more likely to see and repost shorter messages.

Home Photos & Videos Messages Search Sign out

Name _____ @ _____ Username

Your Posts Following Followers
10 145 99

Profile Picture

Mission Statement

Followers

Progression of Understanding: Putting It All Together

Name: _____ Date: _____

What I learned from my research at home:
(look back at your question from your first BWL)

Making Connections:

1. What is the connection between the Shenandoah salamander and global climate change?

2. If you were going to contact your local policymakers about climate change, who would you contact and what would you say to them?

3. What actions should the natural resource managers at Shenandoah National Park do to manage the endangered Shenandoah salamander in light of a changing global climate?

4. Why do you think there is an ongoing debate about whether we as a society, country, etc. should take actions to mitigate global climate change?

Carbon Footprint and Pledge

How many Planet Earths would we need if everyone lived like you? _____

Which sector (piece of the pie chart) contributes the most carbon to your carbon footprint?

_____

Now click "explore scenarios" in the box on the bottom right. Write down the given action items and explain why you could or could not make these changes in your own life.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

If you implemented the suggested changes, you could reduce your footprint by how many Planet Earths?

_____

Carbon Footprint Pledge

I, _____
(write your name here)

Hereby pledge that I will…

_____
_____
_____
_____
_____
_____
(write your activity here)

Lesson 2 – Sampling for the Red-backed Salamander
On-Site Lesson

Introduction:
Students will be in Shenandoah National Park conducting a habitat study on the commonly found red-backed salamander. This procedure is modeled after the Shenandoah salamander research done in 2011. The goals of the park research are to determine what affect changing climate factors such as temperature and moisture conditions may have on high elevation habitats, and how competition with the closely related red-backed salamander may impact the survival of the Shenandoah salamander. Students will be led to the transect site and given further instruction by the lead ranger for the field trip.

Instructional Objectives:
1. Students will learn how to do a transect study on the more common red-backed salamander.
2. Students will gather and analyze red-backed salamander data (size, location, behavior, and color morph).
3. Students will determine abiotic factors in red-backed salamander habitat (air temperature, humidity, wind speed, soil moisture, and pH).

Previous Knowledge Needed:
Completed Lesson 1 Pre-visit
Ability to follow proper sampling and salamander handling techniques

Time to Complete: Approximately 2 hours plus travel time to Shenandoah National Park

Materials needed:
Student field guide
Sampling equipment provided by ranger
Optional: Cameras – video, still, and/or cellular phone camera

Procedure:
A. Visiting a National Park
Schedule your field trip with the Shenandoah National Park Education Office. Make arrangements for transportation and chaperones. Remind students about the time and date, appropriate dress, personal needs, and behaviors expected for the field trip.

For an effective learning experience, please remember the following:
- Bring enough competent chaperones to assist on the field trip. The park requires 1 adult for every 10 students.
- Review appropriate dress for the cooler temperatures on the mountain and behavior expectations for the field trip.
- Plan for lunch or snacks. School groups are welcome to picnic in the park after the program. Picnic areas offer picnic tables and restrooms, but there are no shelters for inclement weather.

The mission of the National Park Service is to preserve and protect the natural and cultural resources of the nation for all people to enjoy. It is important for today's park visitors to practice good stewardship ethics and behaviors in order to pass these unique natural and historical treasures on to future generations in an *unimpaired* condition.

We recommend following **Leave No Trace** (LNT) principles when going on a field trip. There are seven LNT principles:

- Plan Ahead and Prepare
- Travel (and Camp) on Durable Surfaces
- Dispose of Waste Properly
- Leave What You Find
- Minimize Campfire Impacts
- Respect Wildlife
- Be Considerate of Other Visitors

Following these principles and park rules will help make your park visit a safe, successful learning experience while also caring for park resources. Please see the Leave No Trace link on the References and resources page for more information.

B. Red-backed Salamander Transect Study

Meet the park ranger at the scheduled time and location in Shenandoah National Park. Have the students share with the ranger what they have learned about climate change and the Shenandoah salamander and what they hope to discover on the field trip.

At the field research site, the ranger will guide the students to follow the sampling procedures practiced at the school. Divide students into the four research teams, review sampling and salamander handling procedures, and distribute transect study equipment and materials. Review task assignments for searching, measuring, and recording data. Students will lay out their transect line, search for salamanders, take measurements, and record data while practicing proper searching and handling techniques. When completed, each team will keep their data record sheets for analysis back in the classroom.

In addition, during your visit the ranger will lead the students through a few brief discussions before gathering data at the transects, while at the transects, and after gathering data at the transects. These discussions will focus around the following questions:

- What do the students know about climate change?
- What causes climate change (both natural and anthropogenic causes)?
- What do students know about the Shenandoah salamander and the red-backed salamander (including the physical characteristics, habitat, and range of the different salamanders)?
- What challenges does the Shenandoah salamander face?
- What does it mean if a species is endangered?
- How do scientists study salamanders?
- How could the weather conditions affect the success of sampling?

- Compare the conditions of the different transects.
- What correlations might exist between the number of salamanders found in each transect and the habitat conditions of the sampled transects?
- What might the number of salamanders indicate about the habitat preference for this population of red-backed salamanders in the sampled transects?
- What were the range of measurements of the salamanders (largest and smallest) found in each transect?
- What might the number of salamanders indicate about the health of the population in the sampled transects?
- Do students think the red-backed salamander population is a healthy population and how many red-backed salamanders do they think might be in Shenandoah in similar habitats of damp woods?
- What do students think about the health of the population of Shenandoah salamanders?
- What do students think is going to happen to the Shenandoah salamander if climate change continues to warm and dry the mountain tops?
- What do students think is going to happen to the Shenandoah salamander if the red-backed salamander continues to compete with the Shenandoah salamander for habitat?
- What options would students suggest Shenandoah National Park take to manage the population of Shenandoah salamanders? Discuss the feasibility of the different management options.
- What do students think they can do to help the Shenandoah salamanders now that they know about climate change, the research conducted about the Shenandoah salamander, the red-backed salamander, and the challenges to the survival of the Shenandoah salamander?

Lesson 3 – Analyzing Data and Drawing Conclusions
Post-visit Lesson – Teacher Sheet

Introduction:
Students will analyze the red-backed salamander data that they collected in the park during the Lesson 2 On-site Activity and compare to the results that scientists collected on the Shenandoah salamander. They will determine the similarities and differences between the habitat in which they sampled and the habitat in which the Shenandoah salamander can be found. They will then interpret their comparisons in light of global climate change projections and make conclusions about how climate change may impact these salamanders.

Instructional Objectives:
1. Students will compare and analyze data from Shenandoah salamander research.
2. Students will make conclusions/predictions on the survival of the Shenandoah salamander and the red-backed salamander in the park.

Previous Knowledge Needed:
Completed Lesson 1 Pre-visit
Completed Lesson 2 on-site data collection
Knowledge of reading and interpreting data

Time to Complete: 1 class period

Materials Needed:
Student field guide
Student data sheets from Lesson 2 On-site activity with data collected in the park
Computer with a spreadsheet program (optional for graphing)

Procedure:
A. Field Data Analysis
Have the student research teams analyze their data collected in the field and make conclusions about the red-backed salamanders found in that area. What were the abiotic conditions at the transect site (air temperature, relative humidity, wind speed, soil moisture and pH)? Were any salamanders found? Were they active? Were both red-backed color morphs found and how many of each type? Were other salamander species found? If no salamanders were found, propose possible reasons why. Did the field data support what was expected (hypothesis statement)? Design and construct charts and graphs to report findings. Student teams should share data to create a frequency histogram to compare transects and color morph frequency.

B. Comparing Two Sites of the Shenandoah Salamander Field Study

Site	Location	Air Temperature (^{o}C)	Wind Speed (mph)	# of Ground Cover Objects	Shenandoah salamander #	Red-backed salamander #
19	Edge of range of Shenandoah salamander	21.5	2	117	0	6
20	Historic range of Shenandoah salamander	23.8	3	86	2	0

Look at the above table from a study of the Shenandoah salamander completed in the summer of 2011 and complete the following questions.

1. Based on the number of ground cover objects listed, which site is mostly likely forested, and which site is most likely rocky terrain?
   Site 19, at the edge of the salamander range, has more ground cover indicating that it is in a forested habitat. Site 20 is most likely in rocky terrain.

2. Which type of ground cover do you think would keep the ground cooler and moister, forested ground cover or rocky terrain?
   Forested ground cover is more likely to shade out the sun, keeping temperatures lower at ground level. The shade will also prevent evaporation of soil moisture.

3. The data from Site 20 was taken on one of the highest peaks in Shenandoah National Park. Why do you think it has a higher temperature than site 19?
   Even though cooler temperatures are the norm at higher elevations, the lack of ground cover allows more solar radiation to be absorbed at ground level.

4. If global temperatures continue to increase, which site do you think would be more impacted? What does this mean for the endangered Shenandoah salamander?
   Site 20, on the top of the mountain is more likely to be impacted. This may cause additional stress to the endangered Shenandoah salamander.

C. Putting All The Pieces Together

Have students review the Progression of Knowledge, Double Bubble diagram, and field guide graphic organizer sheets with a "think/pair/share" activity focusing on these talking points:

- How are the two salamanders alike in appearance and behavior?
- Where do they live? What habitats do the two salamanders prefer?
- Where did we find red-backed salamanders?
- Did they all look alike? Were any other species of salamanders found?
- What were the temperature, humidity, and soil readings in the transect area?
- Why didn't we find Shenandoah salamanders in our study area?

Next, lead a discussion on what the students learned about climate change, the two salamander species, and their transect study experience. Have the students answer the following:

- What is the relationship between red-backed salamanders and Shenandoah salamanders in Shenandoah National Park?
- If climate conditions change (increase in temperature and reduction in humidity), what might happen to the Shenandoah and red-backed salamanders?
- Where could the Shenandoah salamander go to find suitable (cooler, wetter) habitat? Would it still compete for habitat with the red-back salamander?
- What could park resource managers do to protect/preserve necessary habitat for the endangered Shenandoah salamander, as well as the common red-backed salamander?
- If there was a major change in your community such as a new road, housing development, or shopping center, how would the habitat change for the residents (plants, animals, and people)? Could they all adapt to the changes?
- How can citizens help improve habitats, even those far from their own community?
- What can citizens do to reduce their contributions to climate change that would help to improve environmental conditions and protect/preserve habitats for endangered species?

Lesson 4 – Introduction to Climate Science
Post-visit Lesson – Teacher Sheet

Introduction:
Students will complete simulations to introduce them to the concept of the greenhouse effect and how different atmospheric gases interact with two types of solar radiation to contribute to the global increase in temperature. They will then analyze data provided by NOAA and NASA to determine the relationship between increasing carbon dioxide levels and increasing global temperature anomalies. Finally, students will interpret an informational diagram about the pathways in which carbon dioxide enters and exits the atmosphere. They will also explore recent trends in atmospheric carbon dioxide levels.

Instructional Objectives:
1. Students will synthesize information from online simulations, graphs, and diagrams to determine the impact of increasing greenhouse gas concentrations on global temperatures.
2. Students will analyze real data related to trends in levels of greenhouse gases and global temperature anomalies.
3. Students will understand both where carbon dioxide comes from and where it is stored on Earth.

Previous Knowledge Needed:
Knowledge of reading and interpreting data
General knowledge related to climate change and the greenhouse effect gathered through the participation in previous lessons

Time to Complete: 1 to 2 class periods

Materials Needed:
Computer with internet access
To utilize PhET models, you may need to register with the website. It is a free and easy registration.
Lesson 4 Student Worksheets

Procedure:
A. PhET Greenhouse Effect
Students will complete simulations using a PhET model (link is available on the References and resources page).

Each simulation is described on the student worksheet "A. PhET Greenhouse Effect", "Task I: Greenhouse Simulation" through "Task III: Photon Absorption." Please note that your students might have slightly different temperatures and concentrations than those listed on the answer key.

Discussion Question: Picture yourself sitting in an enclosed car on a sunny day, how does it feel? Why is it important to *not* leave children or pets in a car unattended?

1. Hypothesize why the inside of the car feels so much warmer than its surroundings on sunny days.
   One possible hypothesis:
   Infrared radiation comes in through the windows but cannot escape, thus making the car warmer.

2. Go to the PhET model website on the References and resources page. Click "run now."

Task I: Greenhouse Simulation

This simulation considers two types of solar energy, one you can see (visible sunlight) and one you can feel (infrared). These energies are represented by glowing dots called photons in this simulation.

1. Select the "Glass Layers" tab at the top of the simulation.
   a. What do the yellow dots represent? visible sunlight photons
   b. What do the red dots represent? infrared photons (that can be felt)

2. Allow the photon interaction to stabilize and record the approximate temperature "inside the greenhouse" before adding any glass panes.
   a. What is the temperature *without* glass panes? *-1°F*

3. Add one glass pane.
   a. What do the visible light photons do when they hit the glass *from the top?*
      They pass through the glass pane.
   b. What do the infrared photons do when they hit the glass *from the bottom?*
      Some pass through, some bounce off, some are absorbed.
   c. Hit "pause" and record the new temperature "inside the greenhouse."
      86°F

4. Based on the observations of the photons, why does the temperature go up so much?
   Some of the infrared photons are being trapped at ground level by the glass pane.

5. What happens to the temperature as additional glass panes are added?
   The temperature continues to increase.

6. Explain why this happens by observing the photons.
   With more glass panes, more infrared photons are getting trapped at ground level.

7. Predict how these observations might apply to the earth and its atmosphere.
   One possible answer:
   The atmosphere acts as a "glass pane" trapping infrared radiation on the earth's surface making the Earth warm enough to sustain life.

Task II: Earth Simulation

Click on the Earth simulation tab. Note that this simulation still considers two different types of solar energy, and also considers the variables: greenhouse gas concentration, time period, and cloud cover.

1. While the simulation is stabilizing, take note of your tool panel on the right-hand side of the screen. Note that you are observing the atmosphere of today.
   a. Which greenhouse gases are considered in this simulation?
      Water vapor (H_2O), Carbon dioxide (CO_2), methane (CH_4), Nitrous oxide (N_2O)
   b. Once the thermometer is stabilized, what is the average global temperature for the "today" time period (you may want to "pause" the simulation to get the temperature)?
      __*60°F*__

2. Observe the behavior of the photons. Looking at the photons:
   a. What happens to the sunlight photons when they hit the ground?
      The yellow sunlight photons are absorbed.
   b. What happens to the infrared photons when they hit the ground?
      Some are absorbed, some bounce off the ground and back into the atmosphere.
   c. Are the photons' behaviors more similar to the greenhouse simulation with the glass panes or without the glass panes?
      They should be more similar to the simulation with the glass panes, because the greenhouse gases act as "glass panes" in a greenhouse.

3. Now reduce the greenhouse gas concentration to "none" and observe.
   a. Are the photons' behaviors more similar to the greenhouse simulation with the glass panes or without the glass panes?
      They should be more similar to the simulation without the glass panes because there are no greenhouse gases to trap the infrared photons at the Earth's surface.
   b. What is the average global temperature for this time period *without* any greenhouse gases?_____*-1°F*_____

4. Increase the greenhouse gas concentration to "lots" and observe.
   a. What happens to the appearance of the simulation picture in general?
      The simulation appears to be cloudy or foggy with the addition of "lots" of greenhouse gases.
   b. What is the average global temperature for this time period with *lots* of greenhouse gases?___*70°F*___

5. Considering the behavior of the photons:
   a. Why does the temperature drop so much when there are no greenhouse gases in the atmosphere?
      The temperature drops because there is nothing to trap the infrared radiation at the surface of the Earth.
   b. Why does the temperature increase so much when there are lots of greenhouse gases in the atmosphere?
      The temperature increases because there is an excess of greenhouse gases to trap infrared radiation at the surface of the Earth.

6. Now add three clouds to the simulation.
   a. What happens to the temperature when you add the clouds?
      The temperature should increase with the addition of the clouds.
   b. How are the photons affected by the clouds (observe the photons both above and below the clouds)?
      Visible light photons pass through the clouds and fall to the ground, or are reflected off the tops of the clouds. Infrared photons bounce off the tops of the clouds back into space, bounce off the bottom of the clouds and stay at ground level, or pass through the clouds.

7. Finally, toggle between the three time periods in the simulation and fill in the table below:

Time Period	Today	1750	Ice Age
Average temperature	60 °F	58 °F	28 °F
Concentration of each of the listed greenhouse gases	H_2O 70% CO_2 388ppm CH_4 1.843 ppm N_2O 0.317 ppm	H_2O 70% CO_2 280 ppm CH_4 0.730 ppm N_2O 0.270 ppm	H_2O n/a CO_2 180 ppm CH_4 0.380 ppm N_2O 0.215 ppm

   a. What do you observe about the differences in average global temperature and concentration of greenhouse gases between these time periods?
      As time moves forward, greenhouse gas concentrations increase and temperature also increases.
   b. Why do you think this simulation uses the year 1750 as a time period of interest?
      This time period is before the beginning of the industrial revolution. Humans were still emitting greenhouse gases through small-scale deforestation and farming activities.

8. How does the "greenhouse effect" affect the temperature on the earth?
   The greenhouse effect traps infrared radiation at the surface of the Earth making the temperature on the surface warmer than it would be otherwise.

9. How is the greenhouse effect similar to blankets on a bed?
   Adding more greenhouse gases traps more infrared radiation at the Earth's surface in the same way that more blankets will trap more body heat.

10. What are some of the positive and negative implications of the greenhouse effect?
    The greenhouse effect is essential to supporting life on Earth (otherwise it would be too cold), but too many greenhouse gases will cause temperature increases that could result in increasing severity and number of storms, rising sea levels, melting ice caps, loss of habitat, increased desertification, shifts in where crops can grow, spread of infectious diseases, etc.

11. What assumptions do you think the model is making? Do you think those assumptions are valid?
    These models assume that all land masses are the same, they do not consider the impacts from large bodies of water, they make assumptions about the behavior of photons, and that a complex system responds in the same way as this simplistic version. Overall these assumptions are valid for drawing conclusions as to the nature of the greenhouse effect in general.

12. Identify some natural or human processes that might increase or decrease the amount of greenhouse gases in the atmosphere.
    - *Human ways of increasing greenhouse gases: burning fossil fuels for electricity and transportation, deforestation, land conversion, raising cattle and other livestock, water intensive farming such as rice cultivation or cranberry farming, making concrete.*
    - *Natural ways of increasing greenhouse gases: respiration, volcanic emissions, decomposition, natural releases of methane from aquatic habitats, natural forest fires.*
    - *Human ways of decreasing greenhouse gases: planting trees and other photosynthetic organisms, curtailing the use of fossil fuels, regulating methane emissions from oil and natural gas wells, limiting the amount of deforestation or tree harvesting and requiring reforestation of harvested areas, planting green rooftops, utilizing zero emission energy sources, limiting transportation emissions, using more energy efficient appliances, etc.*
    - *Natural ways of decreasing greenhouse gases: photosynthesis from plants and algae, absorption into the oceans, absorption into plants, soils, sediments and rocks.*

Task III: Photon Absorption

Click on the "Photon Absorption" tab. You will now be looking at how the two different types of solar energy affect different gases found in the atmosphere. You will work with a partner for this simulation.

1. Set a timer for 20 seconds. When you are ready, one person will start the timer while the other slides the photon emitter slider to the middle of the line (this controls how fast the photons will shoot out). Make sure you are shooting out "infrared photons."

2. Start the timer. Then, in your heads, count how many of the infrared photons get absorbed by the molecule (making the molecule "wiggle") and then get shot back out in 20 seconds.

3. After time is up, compare your results and record the number in the chart below #5.

4. Click to the next atmospheric gas on the right-hand side of the screen and repeat the counting procedure.

5. After you have recorded the number of infrared photons absorbed by all of the gases, switch the photon emitter to "visible photons". Observe what happens to each of the atmospheric gases when visible photons are shot out. You do not need to time this section, just observe for several seconds and record what you see below.

	CH_4	CO_2	H_2O	N_2	O_2
Infrared Photons	# absorbed: _____	# absorbed: _____	# absorbed: _____	# absorbed: _____	# absorbed: _____
Visible Photons	# absorbed: _____	# absorbed: _____	# absorbed: _____	# absorbed: _____	# absorbed: _____

***Nitrogen (N_2) and oxygen (O_2) should not absorb any photons at all. Visible photons will not be absorbed by any gas. Methane (CH_4), carbon dioxide (CO_2), and water vapor (H_2O) should all absorb infrared photons.*

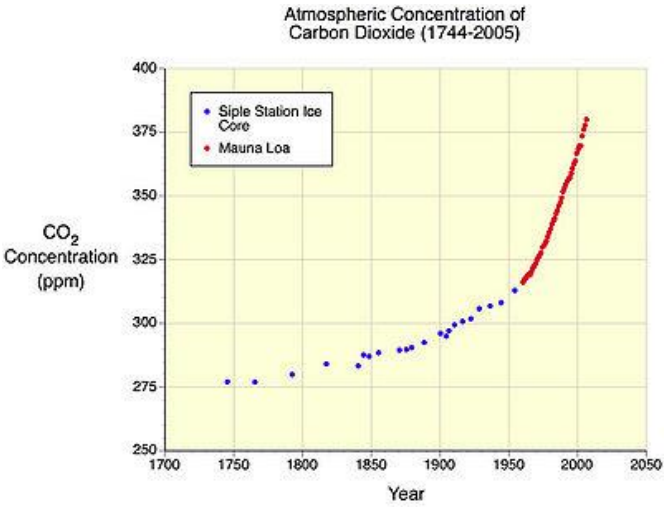
6. Write a conclusion that answers this question, "Which atmospheric gas (CH_4, $C0_2$, H_2O, N_2, or O_2) is the best absorber of infrared photons?"
   Counts of photon absorption will vary and students may not identify methane as the best absorber. Methane (CH_4) is the most potent greenhouse gas, followed by carbon dioxide (CO_2) and then water vapor (H_2O). Neither nitrogen (N_2) nor oxygen (O_2) are greenhouse gases.

7. Based on what you have seen in previous simulations, which of the given atmospheric gases (CH_4, $C0_2$, H_2O, N_2, or O_2) are greenhouse gases?
   CH_4, $C0_2$, H_2O

8. In your own words, explain the relationship between solar energy, greenhouse gases, and temperature.
   Greenhouse gases trap solar energy near to the Earth's surface which causes an increase in temperature.

Background Information on Atmospheric Gases:

Table 1: *Average composition of the Earth's atmosphere up to an altitude of 25 km.*		
Gas Name	**Chemical Formula**	**Percent Volume**
Nitrogen	N_2	78.08%
Oxygen	O_2	20.95%
*Water	H_2O	0 to 4%
Argon	Ar	0.93%
*Carbon dioxide	CO_2	0.0360%
Neon	Ne	0.0018%
Helium	He	0.0005%
*Methane	CH_4	0.00017%
Hydrogen	H_2	0.00005%
*Nitrous oxide	N_2O	0.00003%
*Ozone	O_3	0.000004%
* variable gases		



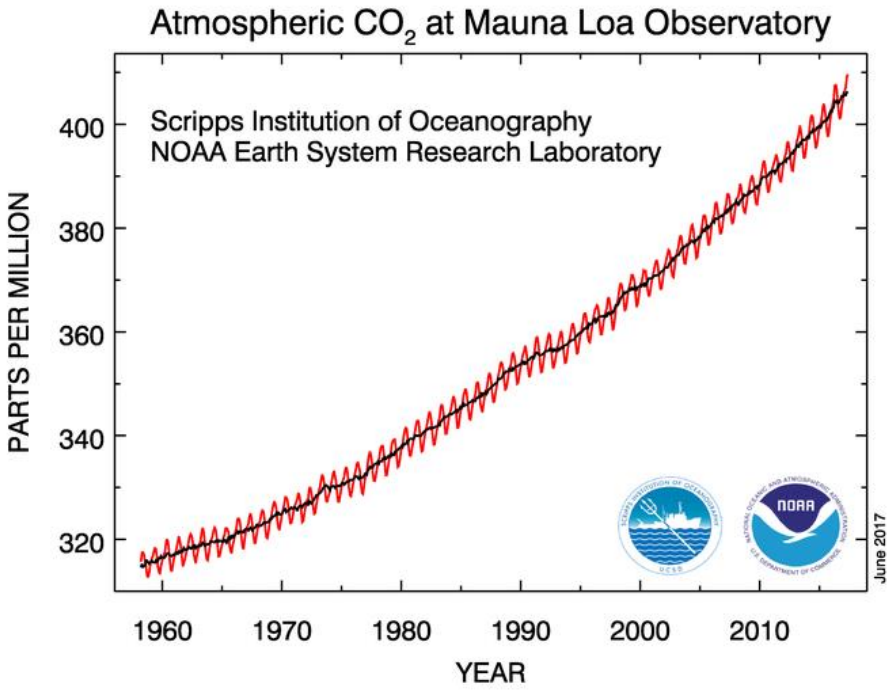
- **CH_4** (methane) is a very strong greenhouse gas. Since 1750, methane concentrations in the atmosphere have increased by more than 150%. The primary sources for the additional methane added to the atmosphere (in order of importance) are: rice cultivation; domestic grazing animals; termites; landfills; coal mining; and, oil and gas extraction.
- The volume of **CO_2** (carbon dioxide) has increased by over 35% in the last three hundred years. This increase is primarily due to human activities such as combustion of fossil fuels, deforestation, and other forms of land-use change. It is now fact—the increase of CO_2 is causing global warming through an enhancement of the greenhouse effect.
- **H_20** (water vapor) varies in concentration in the atmosphere both spatially and temporally. Water vapor has several very important functional roles on our planet. For example, the condensation of water vapor creates precipitation that falls to the Earth's surface providing needed fresh water for plants and animals. Additionally, it helps warm the Earth's atmosphere through the greenhouse effect.
- **N_2** (nitrogen) is removed from the atmosphere and deposited at the Earth's surface mainly by specialized nitrogen fixing bacteria, and by way of lightning through precipitation. The addition of this nitrogen to the Earth's surface soils and various water bodies supplies much needed nutrition for plant growth. Nitrogen is *not* a greenhouse gas.
- **O_2** (oxygen) is exchanged between the atmosphere and life through the processes of photosynthesis and respiration. Photosynthesis produces oxygen when carbon dioxide and water are chemically converted into glucose with the help of sunlight. Like nitrogen, oxygen is not a greenhouse gas.

Lesson modified from online source. See References and resources page for website.

B. Real Data Analysis

Students will analyze the Keeling Curve and a graph showing the global annual mean temperature change as recorded by NASA. Answers and teacher discussion points are below.

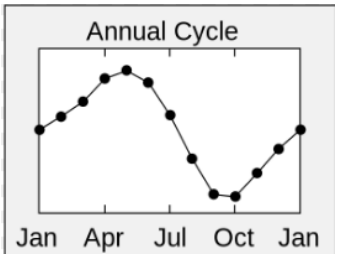
Keeling Curve:



See References and resources page for source website

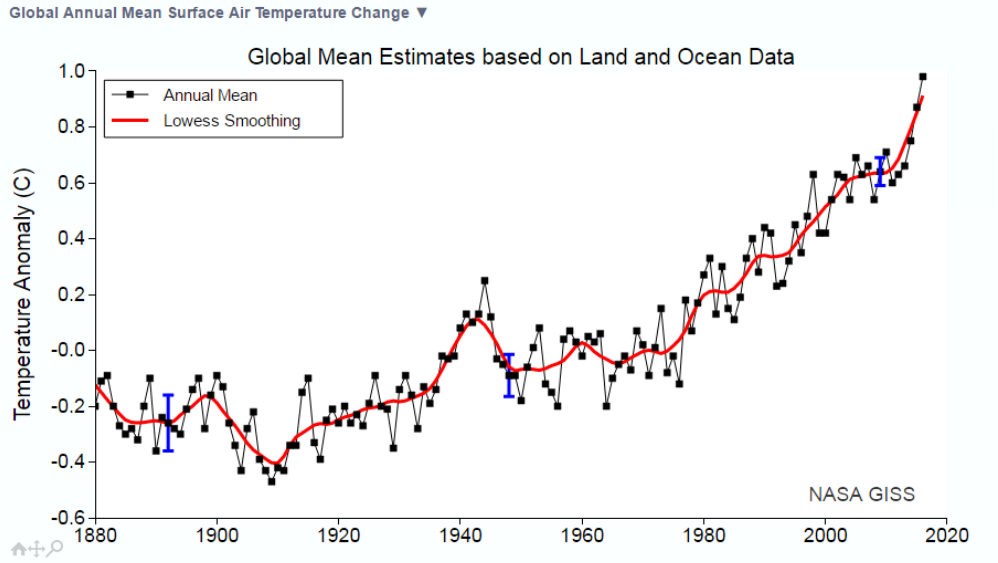
1. What does this graph represent?
   The red line is the real time carbon dioxide concentration at the Mauna Loa Observatory. Oscillations represent the seasonal variation in global carbon dioxide levels on Earth. Carbon dioxide is highest in the springtime (in the Northern Hemisphere) because plants have not been photosynthesizing during the winter. Carbon dioxide concentrations are lowest in the fall (in the Northern Hemisphere) because plants have been using atmospheric carbon dioxide for photosynthesis throughout the summer (see Annual Cycle graph below).

   The black line on the Keeling Curve represents the average carbon dioxide levels after being corrected for this seasonal variation.
   ***Be sure to make this distinction with your students.*



2. What conclusions can you make from this graph?
   Since levels of atmospheric carbon dioxide started getting recorded in 1958, concentration in the atmosphere has steadily increased.

NASA's Global Annual Mean Temperature Change:



Land-ocean temperature index, 1880 to present, with base period 1951-1980. The solid black line is the global annual mean and the solid red line is the five-year lowess smooth. The blue uncertainty bars (95% confidence limit) account only for incomplete spatial sampling. [This is an update of Fig. 9a in Hansen et al. (2010).]

See References and resources page for source website

3. What is a temperature anomaly?
   A temperature anomaly is a departure from the long-term average (reference value). A positive anomaly indicates that the observed temperature was warmer than the average temperature, while a negative anomaly indicates that the observed temperature was cooler than the average.
   (Definition from NOAA, see References and resources page for website)

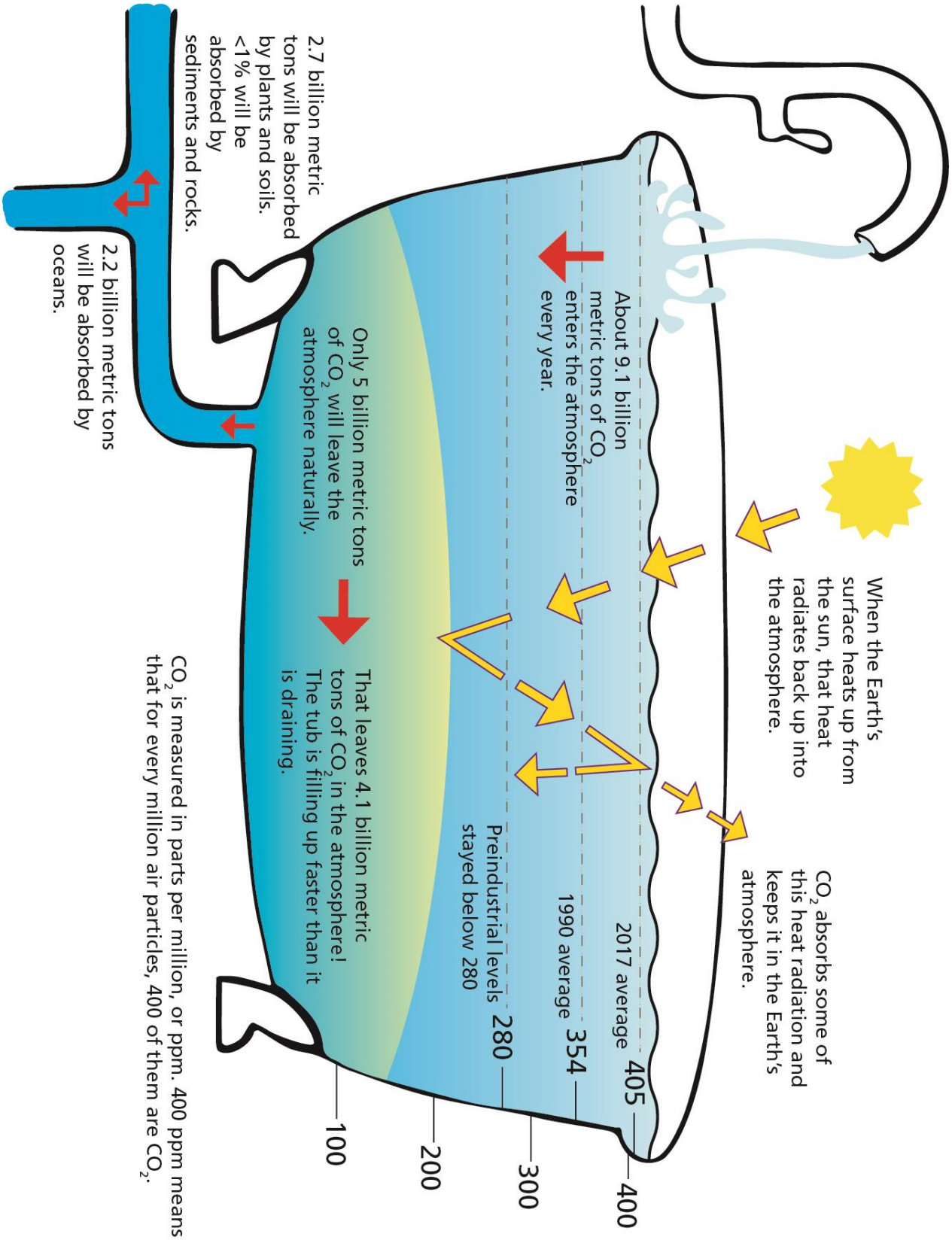
4. What does this graph represent (without using the word "anomaly")?
   This graph represents the years that have had warmer than average temperatures and cooler than average temperatures. The y-axis shows the magnitude of the temperature difference from the long-term average.

5. What conclusion can you make from this graph?
   In recent years, there have been many more years with higher than average temperatures.

6. Based on the conclusions you have drawn from the carbon dioxide and temperature data given by the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA), do you think global warming is occurring on earth? What seems to be the trend?
   Yes, global warming is occurring, and as the level of atmospheric carbon dioxide increases, the number of positive temperature anomalies increases. This indicates a warming trend in global temperatures.

c. Carbon Bathtub Exercise

See References and resources page for source website



Students will interpret the information on the "Carbon Bathtub" informational diagram. Answers and teacher discussion points are available below.

Directions: Answer the questions below using the information on the Carbon Bathtub graphic and your own research.

1. How many metric tons of carbon dioxide are added to Earth's atmosphere each year?
   9.1 billion metric tons

2. How many metric tons of carbon dioxide are removed from the atmosphere each year and stored elsewhere?
   5 billion metric tons

3. What are five ways, man-made and natural, in which carbon dioxide is added to our atmosphere?

   Human ways of increasing greenhouse gases: burning fossil fuels for electricity and transportation, deforestation, land conversion, making concrete.
   Natural ways of increasing greenhouse gases: respiration, volcanic emissions, natural forest fires, ocean-atmosphere exchange, soil respiration.

4. Other than our atmosphere where else is carbon dioxide stored?
   Carbon dioxide is stored in plants, soils, oceans, sediments, and rocks.

5. What does the carbon dioxide stored in our atmosphere do?
   Contributes to the greenhouse effect and causes an increase in global temperature.

6. Complete the table below

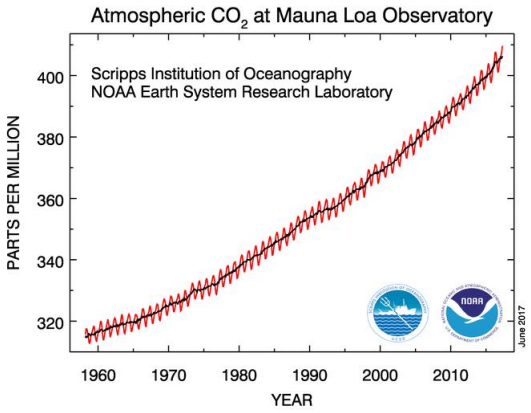
	Difference in carbon dioxide level within time period	Percentage of increase in carbon dioxide levels in the atmosphere	Number of year in time period	Average percentage increase in this time period
preindustrial time (1750) through 1990	*354-280 = 74* (1990 level – 1750 level)	*26%*	*240*	*0.11%*
1990 through 2017	*405-354 = 51* (2017 level – 1990 level)	*14%*	*27*	*0.53%*

* To calculate percentage of increase in carbon dioxide levels in the atmosphere:
1st – Subtract the earliest level of carbon dioxide from the most recent level of carbon dioxide.
2nd – Divide the difference between the two levels by the level of the earliest time.
3rd – Multiply the decimal number by 100. This is the percentage of increase between the two times.

* To calculate the average percentage increase in a time period:
Divide the percentage of increase between the two times by the number of years in that time period.

7. Which time period had the greatest average percentage of increase?
   The time period between 2008 and 2017.
8. Does the average percent increase in each time period support the data shown in the Keeling Curve?
   Yes, the Keeling curve also shows that carbon dioxide concentrations are increasing at a more rapid rate.

Keeling Curve:



See References and resources page for source website

9. Why is it not enough for society to simply maintain current levels of emissions?
   Even if society maintained current levels of emissions, carbon dioxide is being released into the atmosphere almost twice as fast as it is removed, so the atmosphere will continue to "fill" with carbon dioxide.

   ***Teacher note: No one is sure how much carbon dioxide is too much, some scientists think we need to reduce the carbon dioxide level back down to 350 ppm, or the equivalent of 745 billion metric tons of carbon, to avoid serious climate impacts. If current emission trends continue, 450 ppm will be passed well before mid-century.*

Lesson 4 Student Worksheet

Procedure:

A. PhET Greenhouse Effect

Discussion Question: Picture yourself sitting in an enclosed car on a sunny day, how does it feel? Why is it important to *not* leave children or pets in a car unattended?

1. Hypothesize why the inside of the car feels so much warmer than its surroundings on sunny days.

2. Go to the Greenhouse Effect Simulator at the website provided by your instructor. Click "run now."

Task I: Greenhouse Simulation

This simulation considers two types of solar energy, one you can see (visible sunlight) and one you can feel (infrared). These energies are represented by glowing dots called photons in this simulation.

1. Select the "Glass Layers" tab at the top of the simulation.
    a. What do the yellow dots represent? _____
    b. What do the red dots represent? _____
2. Allow the photon interaction to stabilize and record the approximate temperature "inside the greenhouse" before adding any glass panes.
    a. What is the temperature *without* glass panes? _____
3. Add one glass pane.
    a. What do the visible light photons do when they hit the glass *from the top?*
    b. What do the infrared photons do when they hit the glass *from the bottom?*
    c. Hit "pause" and record the new temperature "inside the greenhouse."

    _____
4. Based on the observations of the photons, why does the temperature go up so much?

5. What happens to the temperature as additional glass panes are added?

6. Explain why this happens by observing the photons.

7. Predict how these observations might apply to the earth and its atmosphere.

Task II: Earth Simulation

Click on the Earth simulation tab. Note that this simulation still considers two different types of solar energy, and also considers the variables: greenhouse gas concentration, time period, and cloud cover.

1. While the simulation is stabilizing, take note of your tool panel on the right-hand side of the screen. Note that you are observing the atmosphere of today.
   a. Which greenhouse gases are considered by this simulation?

   b. Once the thermometer is stabilized, what is the average global temperature for the "today" time period (you may want to "pause" the simulation to get the temperature)?

      _____

2. Observe the behavior of the photons. Looking at the photons:
   a. What happens to the sunlight photons when they hit the ground?

   b. What happens to the infrared photons when they hit the ground?

   c. Are the photons' behaviors more similar to the greenhouse simulation with the glass panes or without the glass panes?

3. Now reduce the greenhouse gas concentration to “none” and observe.
    a. Are the photons’ behaviors more similar to the greenhouse simulation with the glass panes or without the glass panes? Why?

    b. What is the average global temperature for this time period *without* any greenhouse gases?

    _____

4. Increase the greenhouse gas concentration to “lots” and observe.
    a. What happens to the appearance of the simulation picture in general?

    b. What is the average global temperature for this time periods with *lots* of greenhouse gases?

    _____

5. Considering the behavior of the photons:
    a. Why does the temperature drop so much when there are no greenhouse gases in the atmosphere?

    b. Why does the temperature increase so much when there are lots of greenhouse gases in the atmosphere?

6. Now add three clouds to the simulation.
    a. What happens to the temperature when you add the clouds?

    b. How are the photons affected by the clouds (observe the photons both above and below the clouds)?

7. Finally, toggle between the three time periods in the simulation and fill in the table below:

Time Period	Today	1750	Ice Age
Average temperature	_____ ^{o}F	_____ ^{o}F	_____ ^{o}F
Concentration of each of the listed greenhouse gases	H_2O _____ CO_2 _____ CH_4 _____ N_2O _____	H_2O _____ CO_2 _____ CH_4 _____ N_2O _____	H_2O _____ CO_2 _____ CH_4 _____ N_2O _____

   a. What do you observe about the differences in average global temperature and concentration of greenhouse gases between these time periods?

   b. Why do you think this simulation uses the year 1750 as a time period of interest?

8. How does the "greenhouse effect" affect the temperature on the earth?

9. How is the greenhouse effect similar to blankets on a bed?

10. What are some of the positive and negative implications of this greenhouse effect?

11. What assumptions do you think the model is making? Do you think those assumptions are valid?

12. Identify some natural or human processes that might increase or decrease the amount of greenhouse gases in the atmosphere.

Task III: Photon Absorption

Click on the "Photon Absorption" tab. You will now be looking at how the two different types of solar energy affect different gases found in the atmosphere. You will work with a partner for this simulation.

1. Set a timer for 20 seconds. When you are ready, one person will start the timer while the other slides the photon emitter slider to the middle of the line (this controls how fast the photons will shoot out). Make sure you are shooting out "infrared photons."
2. Start the timer. Then, in your heads, count how many of the infrared photons get absorbed by the molecule (making the molecule "wiggle") and then get shot back out in 20 seconds.
3. After time is up, compare your results and record the number in the chart below #5.
4. Click to the next atmospheric gas on the right-hand side of the screen and repeat the counting procedure.
5. After you have recorded the number of infrared photons absorbed by all of the gases, switch the photon emitter to "visible photons". Observe what happens to each of the atmospheric gases when visible photons are shot out. You do not need to time this section, just observe for several seconds and record what you see below.

	CH_4	CO_2	H_2O	N_2	O_2
Infrared Photons	# absorbed: _____	# absorbed: _____	# absorbed: _____	# absorbed: _____	# absorbed: _____
Visible Photons	# absorbed: _____	# absorbed: _____	# absorbed: _____	# absorbed: _____	# absorbed: _____

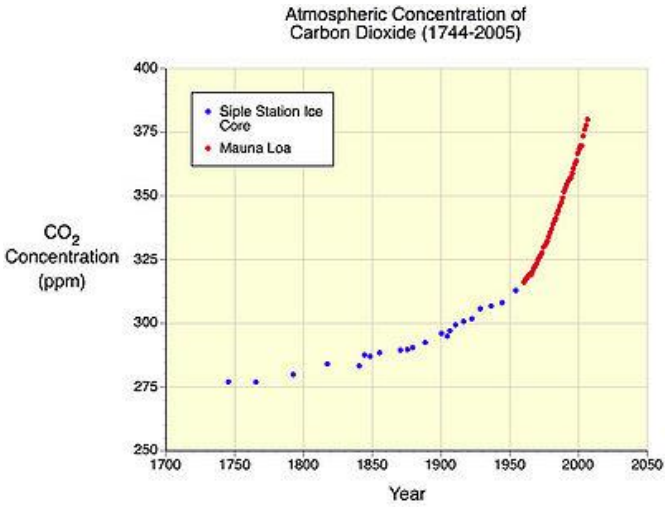
6. Write a conclusion that answers this question, "Which atmospheric gas (CH_4, $C0_2$, H_2O, N_2, or O_2) is the best absorber of infrared photons?"

7. Based on what you have seen in previous simulations, which of the given atmospheric gases (CH_4, $C0_2$, H_2O, N_2, or O_2) are greenhouse gases?

8. In your own words, explain the relationship between solar energy, greenhouse gases, and temperature.

Background Information on Atmospheric Gases:

Table 1: *Average composition of the Earth's atmosphere up to an altitude of 25 km.*		
Gas Name	**Chemical Formula**	**Percent Volume**
Nitrogen	N_2	78.08%
Oxygen	O_2	20.95%
*Water	H_2O	0 to 4%
Argon	Ar	0.93%
*Carbon dioxide	CO_2	0.0360%
Neon	Ne	0.0018%
Helium	He	0.0005%
*Methane	CH_4	0.00017%
Hydrogen	H_2	0.00005%
*Nitrous oxide	N_2O	0.00003%
*Ozone	O_3	0.000004%
* variable gases		

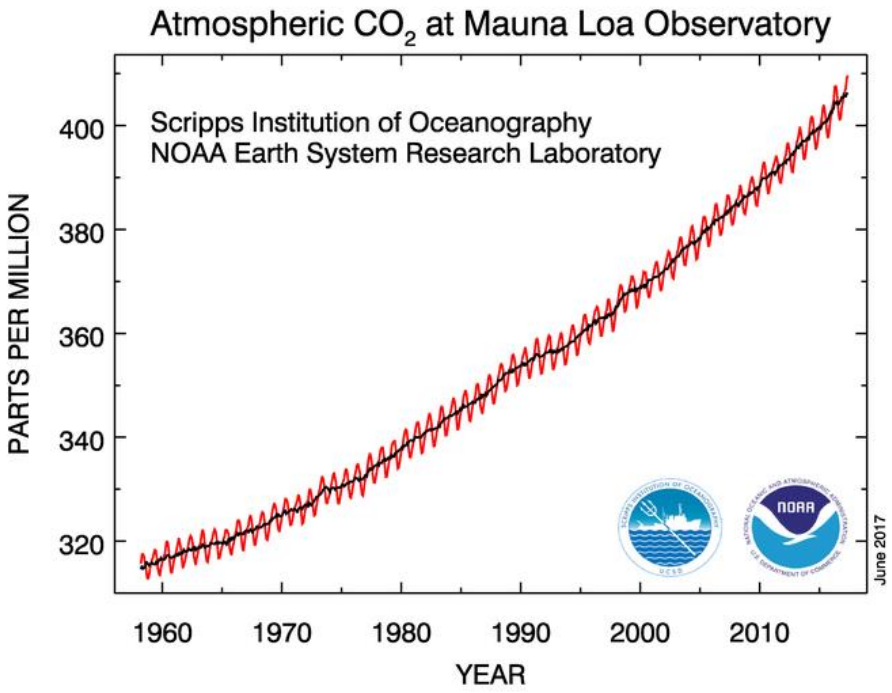


- **CH_4** (methane) is a very strong greenhouse gas. Since 1750, methane concentrations in the atmosphere have increased by more than 150%. The primary sources for the additional methane added to the atmosphere (in order of importance) are: rice cultivation; domestic grazing animals; termites; landfills; coal mining; and, oil and gas extraction.
- The volume of **CO_2** (carbon dioxide) has increased by over 35% in the last three hundred years. This increase is primarily due to human activities such as combustion of fossil fuels, deforestation, and other forms of land-use change. It is now fact—the increase of CO_2 is causing global warming through an enhancement of the greenhouse effect.
- **H_20** (water vapor) varies in concentration in the atmosphere both spatially and temporally. Water vapor has several very important functional roles on our planet. For example, the condensation of water vapor creates precipitation that falls to the Earth's surface providing needed fresh water for plants and animals. Additionally, it helps warm the Earth's atmosphere through the greenhouse effect.
- **N_2** (nitrogen) is removed from the atmosphere and deposited at the Earth's surface mainly by specialized nitrogen fixing bacteria, and by way of lightning through precipitation. The addition of this nitrogen to the Earth's surface soils and various water bodies supplies much needed nutrition for plant growth. Nitrogen is *not* a greenhouse gas.
- **O_2** (oxygen) is exchanged between the atmosphere and life through the processes of photosynthesis and respiration. Photosynthesis produces oxygen when carbon dioxide and water are chemically converted into glucose with the help of sunlight. Like nitrogen, oxygen is not a greenhouse gas.

Lesson modified from online source. See References and resources page for website.

B. Real Data Analysis

Keeling Curve:

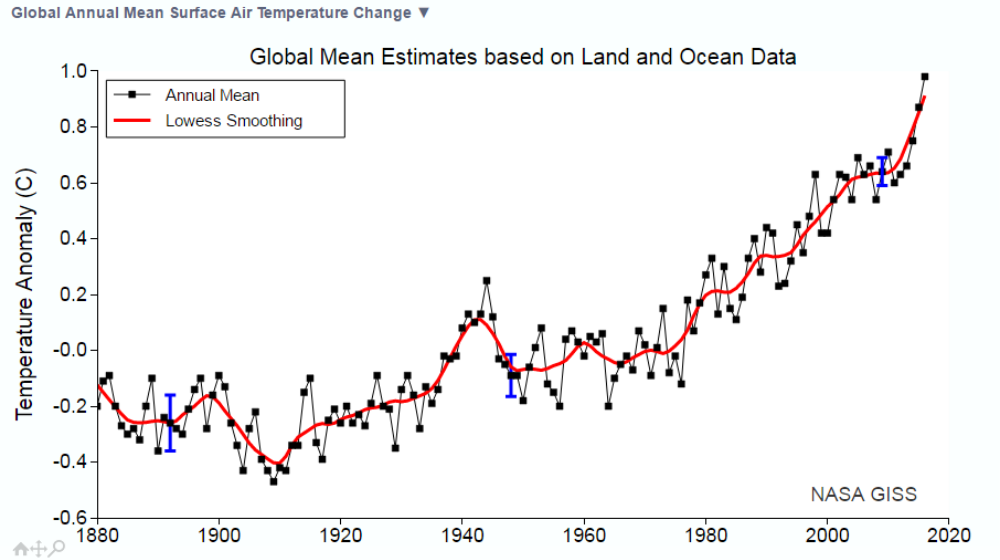


See References and resources page for source website

1. What does this graph represent?

2. What conclusions can you make from this graph?

NASA's Global Annual Mean Temperature Change:



Land-ocean temperature index, 1880 to present, with base period 1951-1980. The solid black line is the global annual mean and the solid red line is the five-year lowess smooth. The blue uncertainty bars (95% confidence limit) account only for incomplete spatial sampling. [This is an update of Fig. 9a in Hansen et al. (2010).]

See References and resources page for source website

3. What is a temperature anomaly?

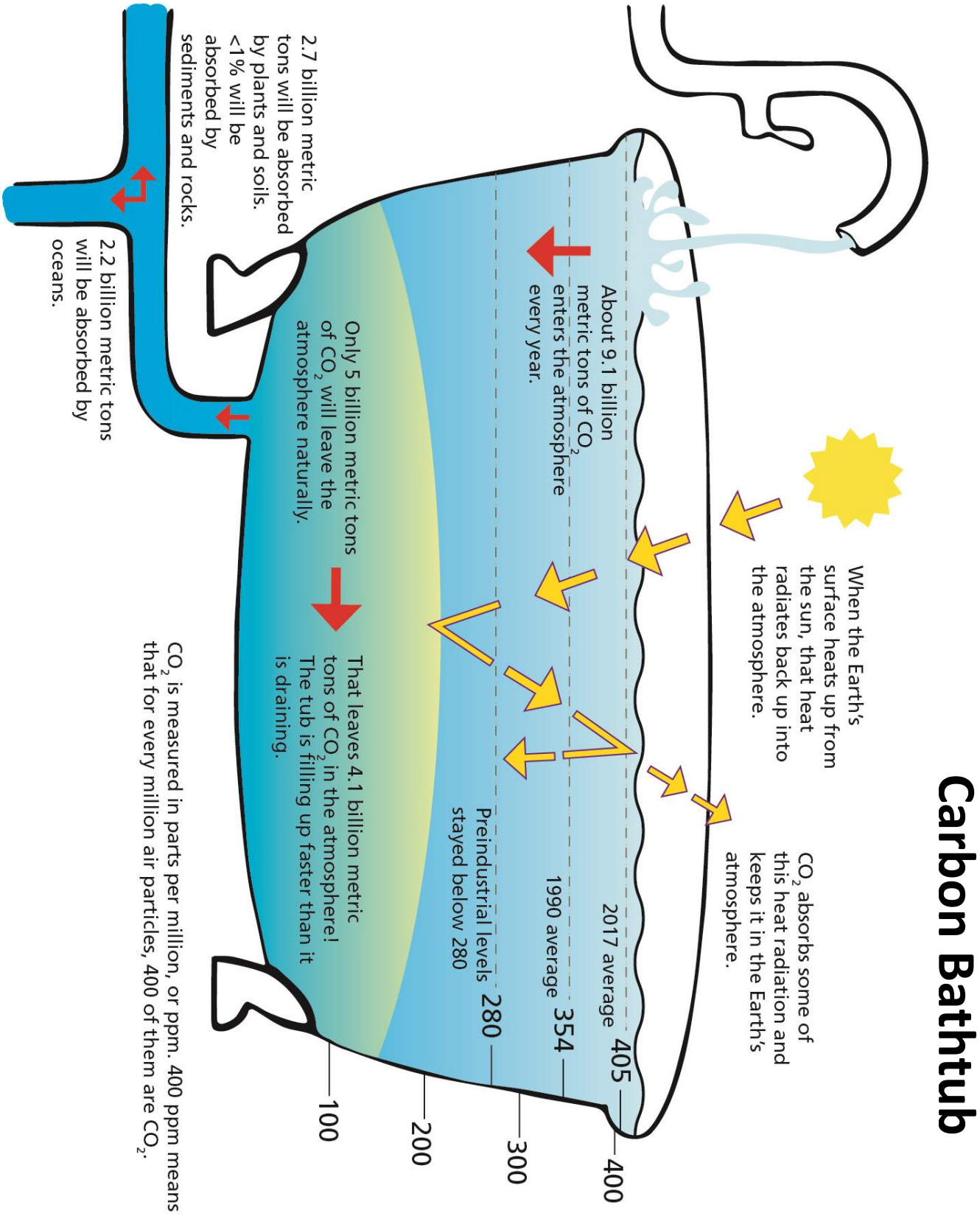
4. What does this graph represent (without using the word "anomaly")?

5. What conclusion can you make from this graph?

6. Based on the conclusions you have drawn from the carbon dioxide and temperature data given by the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA), do you think global warming is occurring on earth? What seems to be the trend?

C. Carbon Bathtub Exercise

See References and resources page for source website



Directions: Answer the questions below using the information on the Carbon Bathtub graphic and your own research.

1. How many metric tons of carbon dioxide are added to Earth's atmosphere each year?

2. How many metric tons of carbon dioxide are removed from the atmosphere each year and stored elsewhere?

3. What are five ways, man-made and natural, in which carbon dioxide is added to our atmosphere?

4. Other than our atmosphere where else is carbon dioxide stored?

5. What does the carbon dioxide stored in our atmosphere do?

6. Complete the table below

	Difference in carbon dioxide level within time period	Percentage of increase in carbon dioxide levels in the atmosphere	Number of year in time period	Average percentage increase in this time period
preindustrial time (1750) through 1990	(1990 level – 1750 level)			
1990 through 2017	(2017 level – 1990 level)			

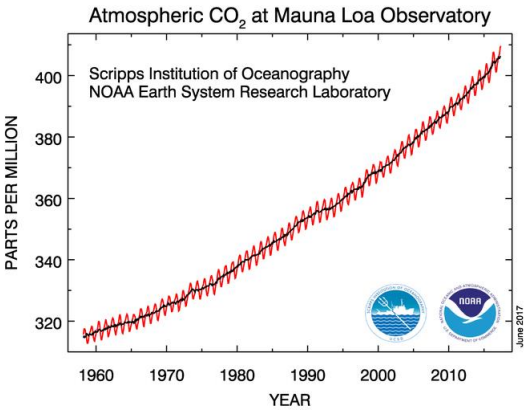
* To calculate percentage of increase in carbon dioxide levels in the atmosphere:
  1st – Subtract the earliest level of carbon dioxide from the most recent level of carbon dioxide.
  2nd – Divide the difference between the two levels by the levels of the earliest time.
  3rd – Multiply this decimal number by 100. This is the percentage of increase between the two times.

* To calculate the average percentage increase in a time period:
  Divide the percentage of increase between the two times by the number of years in that time period.

7. Which time period had the greatest average percentage of increase?

8. Does the average percent increase in each time period support the data shown in the Keeling Curve?

Keeling Curve:



See References and resources page for source website

9. Why is it not enough for society to simply maintain current levels of emissions?

Lesson 5 – Individual Impact on the Climate and Climate Change Communication
Post-visit Lesson

Introduction:
Students will create a social media campaign to educate others about global climate change in Shenandoah National Park. They will also explore how they contribute to global climate change, and how they can curtail their own greenhouse gas emissions.

Instructional Objectives:
1. Students will synthesize the information that they have learned to write clear explanations about how global climate change may impact Shenandoah National Park.
2. Students will educate others about the Shenandoah salamander and climate change.
3. Students will be able to make educated lifestyle choices that reduce their carbon footprint.

Previous Knowledge Needed:
Completed Lessons 1-4
Knowledge of writing within a social media campaign format

Time to Complete: 1 class period

Materials Needed:
Computer and internet access for research
Student field guide

Procedure:
A. Spread the Word about the Shenandoah salamander and climate change
Now that students know about the Shenandoah salamander and the National Park Service's concern for its fragile situation, have your students create a social media campaign using the graphic organizer provided. This campaign should focus on informing the public about climate change, the Shenandoah salamander, and the importance of preserving the high elevation habitats where it lives. Brainstorm a list of ideas for informative and persuasive media messages. Possible topics include:
- The Shenandoah salamander is an indicator species of high elevation ecosystem degradation due to changes in the climate.
- The research being done in Shenandoah National Park on how climate change may affect the Shenandoah salamander and other high elevation ecosystems.
- The importance of reducing the use of fossil fuels to reduce human-caused climate change.

B. Putting It All Together
Answer the questions on the "Putting it All Together" page using the information you gathered from pre-visit activities, the field visit, and the information they gathered for their social media campaign.

C. Investigate how humans contribute to climate change

- Watch the video *Green Ninja: Footprint Renovation* about carbon footprints (see link on References and resources page). Alternatively, the teacher can opt to show a video of their choosing regarding carbon footprints. However, be sure that the video you use targets effective energy-saving behaviors (i.e. turning off lights saves relatively little energy; a more effective behavior would be replacing incandescent light bulbs with LED or CFL bulbs).
- Afterwards, come up with a class definition of a "carbon footprint" and discuss how students contribute to their carbon footprint.
- Have the students calculate their own "Carbon Footprint" using the calculator provided on the References and resources page. Once they have calculated their footprints, have them write down how many earths we would need if everyone lived like they did and where most of the energy that they use comes from (transportation, food, shelter, etc.) on the sheet provided.
- Have them determine what actions they could take to reduce their carbon footprints. Discuss why they could or could *not* make these changes in their lives. Note how the number of earths changes if they accept one or more of the scenarios. Discuss and compare.
- Discuss what families can do, communities can do, and countries can do to reduce their carbon footprints.
- Have each student write and sign a pledge for how they will reduce their carbon footprints, hopefully in the area in which they release the most carbon dioxide.

D. Extended Public Service Message

In addition to creating a social media campaign, students could also work individually or in groups, to create a public service message or program to present to the school board, PTA, park managers, or local citizens' groups. They could use multimedia programs or social media to create a podcast, movie, or publication. These programs should demonstrate students' views on the importance of preserving high elevation habitats and the Shenandoah salamander and ways that individuals can reduce the use of fossil fuels to slow down climate change.

Going Further

1. Research other resource issues in Shenandoah National Park. Links are provided on the References and resources page. Possible topics include:

   <u>Air and Water Quality</u>
   - Acid Deposition
   - Ozone
   - Visibility and Haze
   - Water Quality

   <u>Invasive Species</u>
   - Hemlock trees/Wooly adelgid
   - Hardwood forests/Gypsy moth
   - Ash trees/Emerald Ash borer

3. Investigate “success stories” of other imperiled species. Possible topics include:
   - Peregrine Falcon
   - Bald Eagle

4. Research other national parks that have serious resource management challenges and report on those to the class.

References and resources

Lesson 1

Climate Change Video
https://www.nps.gov/shen/learn/photosmultimedia/our-changing-world.htm

Shenandoah Salamander Video
https://www.nps.gov/shen/learn/nature/shenandoah-salamander-film.htm

Red-backed salamander info:

- Shenandoah National Park Amphibians
  https://www.nps.gov/shen/learn/nature/amphibians.htm
- Virginia Fish and Wildlife
  https://vafwis.dgif.virginia.gov/fwis/booklet.html?Menu=_.Taxonomy&bova=020043&version=15684
- Virginia Department of Game & Inland Fisheries
  https://www.dgif.virginia.gov/wildlife/information/eastern-red-backed-salamander/
- Virginia Herpetological Society
  https://www.virginiaherpetologicalsociety.com/amphibians/salamanders/eastern-red-backed-salamander/red-backed_salamander.php
- University of Michigan Animal Diversity Web
  https://animaldiversity.org/site/accounts/information/Plethodon_cinereus.html

Shenandoah salamander info:

- Shenandoah National Park
  http://www.nps.gov/shen/naturescience/shenandoah_salamander.htm
- Virginia Fish and Wildlife
  http://www.vafwis.org/fwis/booklet.html?Menu=_.Taxonomy&bova=020045
- Virginia Department of Game & Inland Fisheries
  https://www.dgif.virginia.gov/wildlife/information/shenandoah-salamander/
- Virginia Herpetological Society
  https://www.virginiaherpetologicalsociety.com/amphibians/salamanders/shenandoah-salamander/shenandoah_salamander.php
- Fish and Wildlife Service
  https://www.fws.gov/northeast/pdf/ShenandoahSalamander.pdf

General Salamander Information

David, Bishop, and Haas Carola. "Sustaining America's Aquatic Biodiversity - Salamander Biodiversity and Conservation." Virginia Cooperative Extension. Department of Fisheries and Wildlife Sciences, Virginia Tech, 2009. http://pubs.ext.vt.edu/420/420-528/420-528.html

Climate Change

- National Park Service (NPS)
  http://www.nps.gov/subjects/climatechange/index.htm

- Environmental Protection Agency (EPA)
  https://www.epa.gov/climate-indicators
  https://archive.epa.gov/climatechange/kids/index.html
- National Oceanic and Atmospheric Administration (NOAA)
  http://www.climate.gov/
  http://www.cpc.ncep.noaa.gov/
- National Aeronautics and Space Administration (NASA)
  http://climate.nasa.gov/
  http://pmm.nasa.gov/science/climate-change
  http://climatekids.nasa.gov/
- Yale University. "Yale Project on Climate Change Communication." Web. 2013.
  http://environment.yale.edu/climate/

Lesson 4

- PhET Model on the Greenhouse Effect
  https://phet.colorado.edu/en/simulation/greenhouse
- Keeling Curve
  https://www.esrl.noaa.gov/gmd/ccgg/trends/full.html
- NASA Temperature Anomalies Data
  https://data.giss.nasa.gov/gistemp/graphs/
- NOAA Temperature Anomaly Definition
  https://www.ncdc.noaa.gov/monitoring-references/faq/anomalies.php
- Carbon Bathtub graphic
  https://www.climateinteractive.org/media-coverage/national-geographic-features-stermans-carbon-bathtub/

Lesson 5

- Carbon Footprint Video (Green Ninja: Footprint Renovation)
  https://youtu.be/UeYOZgbgG1Q
- Carbon Footprint Calculator
  http://www.earthday.org/take-action/footprint-calculator/
- Carbon Footprint Calculator
  https://depts.washington.edu/i2sea/iscfc/calculate.php

Going Further, Resource Issues

- Park Air Profiles - Shenandoah National Park
  https://www.nps.gov/articles/airprofiles-shen.htm
- Non-native Species
  http://www.nps.gov/shen/naturescience/nonnativespecies.htm
- Nonnative Species Management
  https://www.nps.gov/shen/learn/nature/nonnative-species-management.htm
- Hemlock Woolly Adelgid

http://www.nps.gov/shen/naturescience/eastern_hemlock.htm
https://www.fs.fed.us/research/invasive-species/insects/hemlock-wooly-adelgid.php

- Emerald Ash Borer
  http://www.emeraldashborer.info/

Success Stories of other imperiled species

- Peregrine Falcons at Shenandoah National Park
  http://www.nps.gov/shen/naturescience/falcon.htm
- Endangered Species Success Stories, US Fish and Wildlife Service
  https://www.fws.gov/endangered/map/index.html
- 12 Conservation Success Stories
  https://www.endangered.org/12-conservation-success-stories-for-endangered-species-day/

Teacher resources

Shenandoah National Park Maps
http://www.nps.gov/shen/planyourvisit/maps.htm

Shenandoah National Park Leave No Trace
http://www.nps.gov/shen/planyourvisit/leavenotrace.htm

Double bubble graphic organizer adapted from:
https://www.emaze.com/@AIFFRILC/Strategies-Toolbox_Part-2

Twitter Template Adapted from Twitter Template for Students! (2015, December 10).
http://blogs.henrico.k12.va.us/jpcovais/2014/11/06/twitter-template-for-students/

Print Resources

Cherry, Lynne, and Gary Braasch. “How We Know What We Know about Our Changing Climate: Scientists and Kids Explore Global Warming.” Nevada City, CA: Dawn Publications, 2008.

Gershon, David. “Journey for the Planet: A Kid's Five Week Adventure to Create an Earth Friendly Life.” Woodstock, NY: Empowerment Institute, 2007.

Malnor, Carol. “A Teacher’s Guide to How We Know What We Know About Our Changing Climate – Lessons, Resources, and Guidelines about Global Warming.” Nevada City, CA: Dawn Publications, 2008.

Mathez, Edmond A. “Climate Change: The Science of Global Warming and Our Energy Future.” New York: Columbia UP, 2009.

Schmidt, Gavin, and Joshua Wolfe. “Climate Change: Picturing the Science.” New York: W.W. Norton, 2009.