Grade 7: Gardens, Greenhouses and Global Effects

Stage 1 – Desired Results

Outcomes and Indicators:

Continue the study of plant phenology (initiated during grade 6) by continuing with and augmenting the previous year's research project.

Identify the implications of the Greenhouse Effect upon Earth's temperature by completing a graphic depicting the role of the sun and greenhouse gases and by using the graphic to explain the greenhouse effect to others.

Investigate the Albedo Effect by observing a teacher demonstration OR by engaging in small-group activities to gather and record data.

Identify adaptations and niches of selected plant species of the area by using data and evidence gathered from research to identify how trees respond to changing climate conditions.

Explore the carbon cycle by participating in a carbon cycle role-play and developing a similar role-play using local organisms.

Experience scientific research by participating in a field trip to The Arboretum at Flagstaff and learning directly from the researchers and/or Arboretum staff.

Incorporate knowledge about growing plants and their habitat needs by designing a desktop greenhouse.

Understandings: *Students will understand that . . .*	**Essential Questions:** *Students will ask such questions as…*
Studying and recording the phenology of an organism is a scientifically valid method of recording possible changes in the climate.	Can a tree "relocate" when conditions for life in its current location change?
The Greenhouse Effect is necessary for Earth to sustain life, but the *enhanced* Greenhouse Effect may be problematic for some species.	What is a greenhouse gas? The Greenhouse Effect? The enhanced Greenhouse Effect?
The Albedo Effect is a measure of the amount of heat absorbed or reflected from Earth's surface.	How does the Albedo Effect impact climate?
Scientists use past natural events to predict the future.	How can studying the past give us clues to our future?
Engineers can design man-made habitats for plant growth.	How can a plant survive inside of a building?
The Arboretum at Flagstaff is a scientific, cultural, and educational venue for both researchers and the public.	What is the value of a community resource such as The Arboretum at Flagstaff?

Knowledge: *Students will know . . .*	**Skills:** *Students will be able to . . .*
Scientific research may take years of careful observation and data collection before being used to make valid predictions. Organisms respond to changing climatic conditions by migrating or adapting but not all organisms are able to survive such changes. The Greenhouse is necessary for life on Earth. The Albedo Effect helps maintain the Earth's temperature. Scientists research past history to study trends that may help predict our climate future. Engineers design greenhouses in all shapes and sizes to accommodate plant growth. The Arboretum at Flagstaff is a community resource that provides opportunities for education and research as well as recreation.	*Continued from Grade 6:* *Identify the variables that account for variations in the distribution of plant life.* *Make observations and analyze data collected personally and from historical sources.* *Make inferences based on scientific data.* *Communicate results of an investigation.* Grade 7: Analyze data from historical records. Compare and contrast historical records with current records. Design a functional desktop greenhouse and evaluate its effectiveness for growing plants. Make inferences about the future climate of an area based upon historical and current trends.

Key Vocabulary:

Note for teachers: it is important that students review vocabulary introduced during grade 6:

Annual – Biennial - Climate - Meteorology - Native plant - Perennial - Phenology - Precipitation - Protocol - Qualitative data - Quantitative data - Weather

Additional vocabulary for grade 7:

Albedo Effect: the percentage of the sun's energy reflected by a surface

Atmosphere: a layer of gases surrounding Earth

Carbon cycle: the natural movement of carbon throughout the Earth's spheres (atmosphere, lithosphere, hydrosphere, biosphere)

Dendrochronology: also known as tree-ring dating, is the scientific method of dating based on the analysis of patterns of tree growth rings.

Elevation: the height above a specific reference level (sea level)

Greenhouse Effect: the process of the Earth being warmed by heat (from the sun) that is re-radiated back to Earth and absorbed by greenhouse gases, keeping the planet at an average temperature of approximately 57° F.

Greenhouse gas: atmospheric gases found within Earth's atmosphere; the four major greenhouse gases are carbon dioxide, water vapor, methane, and nitrous oxide

Habitat: the environment where a plant or animal naturally grows and lives

Hydrosphere: combined areas on, under, and over the Earth that contain water

Lithosphere: outermost shell of a planet ("crust" of the Earth)

Urban heat island: phenomenon where the temperatures of cities ("islands") are higher than those of the surrounding area due to human impacts such as roads, buildings, parking lots, other structures that retain heat

Stage 2 – Assessment Evidence

Performance Tasks:

Reinforced from grade 6:

Student log/journals/graphs kept up to date with accurate data, organized so the student may readily extract information

Established protocols used consistently for gathering and recording data and evidence

Frequent *data collection* indicated within journal/log

Additional for grade 7:

Graphic organizer ("Greenhouse Effect") used to accurately describe the greenhouse effect and the enhanced greenhouse effect

Active participation in the Albedo Effect and the carbon cycle role play

Map and information ("Geographic Distribution of Plant Species") acquisition for selected plants

Design a desktop greenhouse to demonstrate knowledge of plant growth needs

Other Evidence:

On task with questions

Demonstrates enthusiasm for learning

Individual motivation and group cooperation

Active participation in all class activities

Well-prepared for class trip to The Arboretum at Flagstaff

Uses time wisely during class trip

Stage 3 – Action Plan

Learning Activities

NOTE: Students will continue the long-term phenology research project launched in grade 6. Project may expand to include additional species, depending upon the enthusiasm and self-direction of students.

Engage Guiding question: "Do we live in a greenhouse?"

Part I: "Life in the Greenhouse" activity (pages 28-33 in *A Teacher's Guide to How We Know What We Know About Our Changing Climate*).

Part II: Albedo Effect demonstration OR small-group exploration.

Extension: Have students generate a list of things they can do to mitigate global warming and include this list with a letter that each student writes to their parents or guardians on the importance of acting to reduce global warming.

Explore Guiding question: "How do plants respond when their habitat heats up"

[Find lesson on pages 20-28 of the *Natural Inquirer: Climate Change* edition.]

Part I: On the Move - Complete research as indicated (page 26), selecting from plants that naturally occur within the Flagstaff area.

Part II: Complete the Tree/Shrub Fact File (and maps) and share with class.

Extension: Invite a landscape ecologist, GIS analyst, Wildlife Landscape Ecologist (see page 21 in the *Natural Inquirer*) or other scientist studying plants in your area to visit your classroom.

Explain Guiding question: "Do plants contribute to the Greenhouse Effect?"

Use the Carbon Cycle Role Play to review (or to introduce) students' knowledge of the carbon cycle in nature. Ask what will happen if the trees they have researched are forced to "move" due to a changing climate.

Extension: Students engage in the "Back to the Future" activity (pages 38-49) to understand how dendrochronology contributes to our knowledge of the past. Invite an employee of the Coconino National Forest to bring actual tree cookies to demonstrate the process students have done in class using paper "tree ring" strips.

Elaborate Guiding question: "How do scientists know that the climate is changing in my community?"

Classroom field trips to The Arboretum at Flagstaff to encounter *in situ* field research.

Evaluate Guiding question: "How do I design for STEM growth?"

Students design, build and test a desktop greenhouse

Extension: Small groups create a home page(s) for a website that will share their knowledge with the community.

"Gardens, Greenhouses and Global Effects"

Grade 7: Arizona Academic Standards, Framework for K-12 Science Education, and Climate Literacy Principles

Framework for K-12 Science Education	Arizona Academic Standards	Climate Literacy: The Essential Principles of Climate Science
Scientific and Engineering Practices 1. Asking questions (for science) and defining problems (for engineering) 3. Planning and carrying out investigations 4. Analyzing and interpreting data 5. Using mathematics and computational thinking 6. Constructing explanations and designing solutions 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information **Crosscutting Concepts** 2. Cause and effect: mechanism and explanations 4. Systems and system models 5. Energy and matter: Flows, cycles, and conservation 6. Structure and function 7. Stability and change **Disciplinary Core Ideas** **Life Sciences** LS1.A: Structure and Function LS2.A: Interdependent Relationships in Ecosystems LS2.B: Cycles of Matter and Energy	**Science** **Inquiry** S1C1PO2. Select appropriate resources for background information related to a question, for use in the design of a controlled investigation. S1C2PO1. Demonstrate safe behavior and appropriate procedures (e.g., use and care of technology, materials, organisms) in all science inquiry. S1C2PO4. Perform measurements using appropriate scientific tools (e.g., balances, microscopes, probes, micrometers). S1C2PO5. Keep a record of observations, notes, sketches, questions, and ideas using tools such as written and/or computer logs. S1C3PO1. Analyze data obtained in a scientific investigation to identify trends. S1C3PO2. Form a logical argument about a correlation between variables or sequence of events (e.g., construct a cause-and-effect chain that explains a sequence of events). S1C3PO4. Determine validity and reliability of results of an investigation. S1C3PO5. Formulate a conclusion based on data analysis. S1C3PO7. Formulate new questions based on the results of a previous investigation. S1C4PO1. Choose an appropriate graphic representation for collected data: • line graph • double bar graph • stem and leaf plot • histogram S1C4PO3. Communicate the results of an investigation with appropriate use of qualitative and quantitative information.	2. Climate is regulated by complex interactions among components of the Earth system. A. Earth's climate is influenced by interactions involving the Sun, ocean, atmosphere, clouds, ice, land, and life. Climate varies by region as a result of local differences in these interactions. C. The amount of solar energy absorbed or radiated by Earth is modulated by the atmosphere and depends on its composition. Greenhouse gases—such as water vapor, carbon dioxide, and methane—occur naturally in small amounts and absorb and release heat energy more efficiently than abundant atmospheric gases like nitrogen and oxygen. Small increases in carbon dioxide concentration have a large effect on the climate system. 3. Life on Earth depends on, is shaped by, and affects climate. A. Individual organisms survive within specific ranges of temperature, precipitation, humidity, and sunlight. Organisms exposed to climate conditions outside their normal range must adapt or migrate, or they will perish. B. The presence of small amounts of heat-trapping greenhouse gases in the atmosphere warms Earth's surface, resulting in a planet that sustains liquid water and life. 4. Climate varies over space and time through both natural and man-made processes. A. Climate is determined by the long-term pattern of temperature and precipitation averages and extremes at a location. Climate descriptions can

Transfer Ecosystems LS2.C: Ecosystem Dynamics, Functioning, and Resilience LS4.C: Adaptation **Earth and Space Science** ESS2.A: Earth Materials and Systems ESS2.D: Weather and Climate ESS3.C: Human Impacts on Earth Systems ESS3.D: Global Climate Change	S1C4PO4. Write clear, step-by-step instructions for following procedures (without the use of personal pronouns). S1C4PO5. Communicate the results and conclusion of the investigation. **History and Nature of Science** S2C1PO4. Analyze the use of technology in science-related careers. S2C2PO3. Apply the following scientific processes to other problem solving or decision making situations: • Observing • Questioning • Communicating • Organizing data • Predicting • Inferring • Generating hypothesis • Identifying variables NOTE: Classifying is a part of this PO but is not addressed in this lesson. **Science in Personal and Social Perspectives** S3C1PO1. Analyze environmental risks (e.g., pollution, destruction of habitat) caused by human interaction with biological or geological systems. S3C1PO2. Analyze environmental benefits of the following human interactions with biological or geological systems: • reforestation • habitat restoration Note: construction of dams is part of this PO but is not addressed in tis lesson. S3C1PO3. Propose possible solutions to address the environmental risks in biological or geological systems. S3C2PO1. Propose viable methods of responding to an identified need or problem. **Life Science** S4C3PO2. Explain how organisms obtain and use resources to develop and thrive in: • niches	refer to areas that are local, regional, or global in extent. Climate can be described for different time intervals, such as decades, years, seasons, months, or specific dates of the year. B. Climate is not the same thing as weather. Weather is the minute-by-minute variable condition of the atmosphere on a local scale. Climate is a conceptual description of an area's average weather conditions and the extent to which those conditions vary over long time intervals. F. Natural processes that remove carbon dioxide from the atmosphere operate slowly when compared to the processes that are now adding it to the atmosphere. Thus, carbon dioxide introduced into the atmosphere today may remain there for a century or more. Other greenhouse gases, including some created by humans, may remain in the atmosphere for thousands of years. 5. Our understanding of the climate system is improved through observations, theoretical studies, and modeling. D. Our understanding of climate differs in important ways from our understanding of weather. Climate scientists' ability to predict climate patterns months, years, or decades into the future is constrained by different limitations than those faced by meteorologists in forecasting weather days to weeks into the future. 6. Human activities are impacting the climate system. D. Growing evidence shows that changes in many physical and biological systems are linked to human caused global warming. Some changes resulting from human activities have decreased the capacity of the environment to support various species and have substantially reduced ecosystem biodiversity and ecological resilience.

	NOTE: Predator/prey relationships are a part of this PO but are not addressed in this lesson. S4C3PO3. Analyze the interactions of living organisms with their ecosystems: • limiting factors • carrying capacity S4C3PO4. Evaluate data related to problems associated with population growth (e.g., overgrazing, forest management, invasion of non-native species) and the possible solutions. S4C3PO5. Predict how environmental factors (e.g., floods, droughts, temperature changes) affect survival rates in living organisms. S4C3PO6. Create a model of the interactions of living organisms within an ecosystem. **AZ College and Career Readiness Standards - ELA** Key Ideas and Details • Cite specific textual evidence to support analysis of science and technical texts. **(6-8.RST.1)** • Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. **(6-8.RST.3)** Craft and Structure • Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 6–8 texts and topics.* **(6-8.RST.4)** Integration of Knowledge and Ideas • Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). **(6-8.RST.7)**	

Materials Required – Grade 7: Gardens, Greenhouses and Global Effects

Websites*:*

- http://www.nazflora.org/Image%20index.htm (image index – northern AZ plants)
- http://www.thearb.org/documents/nativePlantsNoAz.pdf (general listing of native trees for N. Arizona)
- http://ltrr.arizona.edu/ (dendrochronology lab at the University of Arizona)
- http://cpluhna.nau.edu/Tools/dendrochronology.htm (overview of "Land Use History of Northern Arizona – Colorado Plateau")
- http://www.sega.nau.edu (Southwest Experimental Garden Array)
- https://www.usanpn.org/nn/species_search (National Phenology Network)

Books/media:

- *A Teacher's Guide to How We Know What We Know About Our Changing Climate* (1 copy for reference)
- *Integrating climate change and genetic research to restore western landscapes,* The Arboretum at Flagstaff [brochure]
- *Climate Change is Happening*, The Arboretum at Flagstaff [brochure]

Photocopies:

- "The Greenhouse Effect" (page 33 from *A Teacher's Guide*…) – 1 copy/student, to insert into student journals when completed
- *Natural Inquirer: Number 14 - Climate Change Edition*, p. 20-28
- Carbon Cycle Role-play cards (printed front and back) – laminating will help preserve these for future use
- Carbon Cycle Role-play Lesson Plan
- *Phenology in Your Backyard* Guide
- Albedo Effect Lesson Plan
- *ChainReaction: An Island in the Sun*

Art supplies:

- Colored pencils (3-4 different colors/student)
- Markers
- Black and white 9"x12" construction paper (1 sheet of each per small group of students, sufficient to completely cover one can)
- Adhesive tape
- String or yarn (approx. 12" per group)
- 6" or 12" rulers or pieces of ¼" dowel (2 per group)
- Scissors (1 per group)
- Blank white paper, 8 ½"x11" (2 sheets per small group of students)

Science equipment:

- Small thermometers (2 per group)

Miscellaneous:

- 2 cans of equal size – e.g., soup cans or vegetable cans (1 set per small group of students)*
- Journals for students [**or** this section may be added to science notebooks if already being used]
- Masking or painters tape
- 21 ping pong balls, each labeled with the letter "C"
- Recycled construction materials for desktop greenhouse

*Make certain that each can is identical – i.e., size, shape, interior color, etc.

Rubric: Desktop Greenhouse – Grade 7

Indicator	4: Exceeds expectations	3: Meets expectations	2: Approaches expectations	1: Falls short of expectations
Engineering Design	Design demonstrates sound planning that addresses the individual needs of the plant. All details have been carefully considered for the plant to be grown.	Design was planned but construction did not adhere to the approved plan. Most details have been considered for the plant to be grown.	Design demonstrates a lack of planning and/or incomplete or haphazard construction. The design shows little consideration for the plant to be grown.	No plan submitted or approved. Construction may have taken place but is unlikely to satisfactorily accommodate the needs of the plant to be grown.
Scientific Accuracy (Recorded Data)	All content is scientifically accurate, used in proper context, and includes detailed notes about the plant: regular observation, date, time, temperature, special steps taken to address any issue - e.g., water, sunlight, sudden changes in temperature. Phenology notes are accurate and sketch or photo may be provided.	Content is generally accurate, used in proper context, and includes notes about the plant: regular observation, date, time, temperature, special steps taken to address any issue - e.g., water, sunlight, sudden changes in temperature. Phenology notes are accurate and sketch or photo may be provided.	Little attention to scientific accuracy, with numerous factual errors and/or omissions.	No attention to scientific accuracy. Information presented is biased and lacks a scientific basis.
Accommodation for Plants	Needs of the specific variety of plant have been carefully considered and are evident. Easy to access plant in the event of unforeseen challenge (e.g., bug infestation, disease, etc.)	Needs of the specific variety of plant have been considered and are generally evident. Plant may be inaccessible due to design of the greenhouse.	Plant is hard to access and may be missing important criteria for growth (sufficient water, sunlight or shade, etc.).	Little thought given to accommodating plant. Plant unlikely to survive long-term without completely destroying the greenhouse.
Completeness and Presentation: Greenhouse, EDP Elements, Ongoing Data	All required elements are gathered, easily accessible, presented in an easy-to-use format.	Presentation may lack an element and/or an element may contain a few errors or missing pieces.	Several elements are lacking, contain errors, or have not been assembled into one presentation.	Most elements are missing. Greenhouse design demonstrates obvious flaws and/or ignorance of the needs of the plant.

Rubric: Home Page for Website – Grade 7

Indicator	4: Exceeds expectations	3: Meets expectations	2: Approaches expectations	1: Falls short of expectations
Scientific Accuracy	All content is scientifically accurate, used in proper context, and supports the overall message of the website. No obvious errors are evident.	Most content is scientifically accurate, used in proper context, and supports the overall message of the website. Some errors may be present.	Little attention to scientific accuracy, with numerous factual errors and/or omissions.	No attention to scientific accuracy. Information presented is biased and lacks a scientific basis.
Understanding of Key Vocabulary	At least 5 key vocabulary words from the lesson are incorporated into the website and are used accurately. Students demonstrate a thorough understanding of each word.	4 key vocabulary words from the lesson are incorporated into the website and are used accurately. Students demonstrate a thorough understanding of each word.	2 or 3 key vocabulary words from the lesson are incorporated into the website and are used accurately. Students demonstrate a basic understanding of each word.	One or no key vocabulary words from the lesson are incorporated into the website but may be used inaccurately. Students demonstrate little understanding of each word.
Audience Appeal	Website is highly engaging to the audience: visually appealing, creative, and encourages additional exploration.	Website is engaging to the audience: visually appealing, creative, and provides an opportunity for additional exploration.	Website does little to engage the audience. May lack visual appeal, creativity, and/or indicates a lack of preparation.	Website does not engage the audience. Lacks visual appeal and creativity. Demonstrates a lack of forethought and preparation.
Team Effort	All members of the group participate equally in designing and developing the website.	Most members of the group participate equally in designing and developing the website.	Few members of the group participate equally in designing and developing the website.	One member of the group carries the assignment by designing and developing the website without benefit of other group members.

Grade 7: Gardens, Greenhouses and Global Effects

Subject & Topic

Science, ACCR – ecology, populations, environmental factors related to populations

Standards are correlated to each segment of this lesson and may be found at the end of this document.

Framework for K-12 Science Education (from NGSS - http://nextgenscience.org/next-generation-science-standards)

This series of lessons for grade 7 correlates to:

Scientific and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Crosscutting Concepts

2. Cause and effect: mechanism and explanations
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
6. Structure and function
7. Stability and change

Disciplinary Core Ideas

Life Sciences

LS1.A: Structure and Function

LS2.A: Interdependent Relationships in Ecosystems

LS2.B: Cycles of Matter and Energy Transfer Ecosystems

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

LS4.C: Adaptation

Earth and Space Science

ESS2.A: Earth Materials and Systems

ESS2.D: Weather and Climate

ESS3.C: Human Impacts on Earth Systems

ESS3.D: Global Climate Change

Objective(s)

1. Continue the long-term phenology project launched in grade 6.
2. Identify the four major greenhouse gases (GHGs) and their impacts upon the Earth, separating those that are manmade from those that occur naturally.
3. Explain the difference between the *greenhouse effect* and the *enhanced greenhouse effect* and explain each to a peer.
4. Observe a classroom demonstration (or participate in an experiment) that identifies the Albedo Effect and its impact upon Earth.
5. Research tree species native to the local region and create a map depicting the current and historical distribution of those species, including a "Tree Fact File" for the classroom.

6. Examine the carbon cycle and the movement of carbon atoms within the lithosphere, atmosphere, biosphere, and hydrosphere.
7. Investigate tree-ring data [dendrochronology] and lessons that can be learned from trees. (optional but recommended).
8. Participate in a field trip to The Arboretum at Flagstaff to reinforce knowledge of plant phenology and to examine working greenhouses.
9. Discover how scientists will use results from the SEGA to plan for/improve restoration and conservation practices of plants in your area.
10. Create a home page for a website that will share your phenology research and learning with your community. [NOTE: This may be information that can be uploaded to The Arboretum's website.]

Evidence of Mastery

The following three are a continuation from grade 6 (phenology research project):

- *Student log/journals* kept up to date with accurate data, organized so the student may readily extract information
- *Established protocols* used consistently for gathering and recording data and evidence
- Frequent *data collection* indicated within journal/log

Additional for grade 7:

Graphic organizer ("Greenhouse Effect") used to accurately describe the greenhouse effect and the enhanced greenhouse effect

Accurate research, maps and information presented for the "Tree Fact File" and distribution map

Active *participation in the field trip* to The Arboretum at Flagstaff

Prototype for a home page (classroom website) demonstrating new learning and results of the phenological research study addressing the question: *"What do we know about how local plants might respond to climate change in this area?" – OR –*

Construction of a greenhouse to germinate and begin seedlings for a native plant species

Key vocabulary:

Review and reinforce vocabulary learned during Grade 6

- *Annual*
- *Biennial*
- *Climate*
- *Meteorology*
- *Native plant*
- *Perennial*
- *Phenology*
- *Precipitation*
- *Protocol*
- *Qualitative data*
- *Quantitative data*
- Weather

Additional vocabulary for grade 7

Albedo Effect: the percentage of the sun's energy

Materials: (items and quantities)

Websites:

- http://www.nazflora.org/Image%20index.htm (image index – northern AZ plants)
- http://www.thearb.org/documents/nativePlantsNoAz.pdf (general listing of native trees for northern Arizona)
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- http://www.sega.nau.edu (Southwest Experimental Garden Array)
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reflected by a surface

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Carbon cycle – the natural movement of carbon throughout the Earth's spheres (atmosphere, lithosphere, hydrosphere, biosphere)

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Greenhouse gas: atmospheric gases found within Earth's atmosphere; the four major greenhouse gases are carbon dioxide, water vapor, methane, and nitrous oxide

Habitat: the environment where a plant or animal naturally grows and lives

Hydrosphere: combined areas on, under, and over the Earth that contain water

Lithosphere: outermost shell of a planet ("crust" of the Earth)

Urban heat island: phenomenon where the temperatures of cities ("islands") are higher than those of the surrounding area due to human impacts such as roads, buildings, parking lots, other structures that retain heat

Books/media:

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Photocopies:

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- Markers
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- Adhesive tape
- String or yarn (approx. 12" per group)
- 6" or 12" rulers or pieces of ¼" dowel (2 per group)
- Scissors (1 per group)
- Blank white paper, 8 ½"x11" (2 sheets per small group of students)

Science equipment:

- Small thermometers (2 per group)

Miscellaneous:

- Journals for students [**or** add to science notebooks if already being used]

	• 2 cans of equal size – e.g., soup cans or vegetable cans (1 set per small group of students)* • Journals for students [or this section may be added to science notebooks if already being used] • Masking or painters tape • 21 ping pong balls, each labeled wth the letter "C" *Make certain that each can is identical – i.e., size, shape, interior color, etc.

Engage

Guiding question: "Do we live in a greenhouse?"

Part I: Life in the Greenhouse

Prepare:

- Review the "Life in the Greenhouse" activity on pages 28-33 in *A Teacher's Guide to How We Know What We Know About Our Changing Climate*.
- Copy "Greenhouse Effect" (page 33) – OR plan to have students create their own diagram in their science journals

Present:

Ask: "What is a greenhouse? Have you even been inside one? What is the purpose of a greenhouse?"

Students should have a basic knowledge of greenhouses before beginning the next part of this lesson. Remind them that they come in a range of designs including cold frames, hoop houses, and biospheres.

Ask: "Have you heard the term 'Greenhouse Effect'? What do you think it means? Is this helpful or harmful to the planet? Why?"

Conduct a brief class discussion, writing down what students identify as being either helpful (pro) or harmful (con). Have them sort these ideas into two categories:

1. Pros - helpful
2. Cons - harmful

Ask: "Can any of the pros also be cons?" And vice versa. Follow up with a brief description on how points of view can differ and that some characteristics exist on a sliding scale, where too much of a good thing can sometimes become a bad thing.

Student activity:

- Follow instructions for the "Life in the Greenhouse" activity on pages 28-33 in *A Teacher's Guide to How We Know What We Know About Our Changing Climate*.
- Students explain the greenhouse effect to a peer, using their completed graphics.

Revisit the questions asked to launch this investigation. What would students like to add to or edit from their original responses? [NOTE: there is no perfect correlation between the greenhouse effect and a greenhouse. Students should know how the two are different. However, "greenhouse effect" is still used in the scientific community to describe the interaction between Earth's atmosphere and the planet.)

Students add their completed graphic organizers to their student journals.

Part II: Albedo Effect demonstration **OR** small-group exploration. [If time is limited, this may be done as a classroom demonstration with students serving as notetakers. If time permits, make this into a true inquiry as students work in small groups to create their own methd of gathering data using the materials provided.]

Prepare:

- Review lesson for teaching the Albedo Effect. (See accompanying lesson.)
- Gather supplies for demonstration or small groups: cans, black and white construction paper, scissors, tape, string or yarn, thermometers.
- Establish the parameters on the school grounds or classroom where students will collect data, ensuring they will be in a safe environment.

Present:

- Ask: "Has anyone ever heard of the Albedo Effect?" (Some will already know the concept but the term may be new to them.)
- Ask: "How can we determine whether light or dark colors absorb more light? How can we measure the amount of light that is being tranformed into heat energy?" Allow a brief classroom discussion.

Student activity:

- Conduct the demonstration using students as notetakers OR have them work in small groups to create their own method for deriving an answer. If using small groups, allocate the identical supplies to each group and alllow them 10 minutes to create their devices. They should also understand they will have to record data so should set up a chart or table to do so. *It is important that they gather data reliably and consistently!*
- Groups set up their equipment outdoors or indoors in the predetermined location and collect data as prescribed. *Recommended*: make recordings of the temperature every 2-3 minutes to ensure there are are least 5 different recordings.
- Groups share their data and create a classroom graph/chart/table to depict their results.

Revisit the guiding question: Do we live in a greenhouse?

Explain the Urban Heat Island Effect and how it is implicated in the Albedo Effect. [Phoenix is a great example! Visit http://chainreactionkids.org/files/issues/6/chreact6_p16_19.pdf with your class. See text below for an excerpted description of implications of this phenomenon.]

Global warming and urban heat islands are both examples of how human beings can affect the weather. But they are not the same thing. Global warming is the average temperature change for the whole world. Urban heat islands are limited to individual cities.

In the 1990s, people used temperatures taken in cities to support the theory of global warming. Because of this, some scientists believed that global warming wasn't really happening. They said that the rising temperatures were actually an effect of urban heat islands, but weren't happening on a global level. Now, scientists are looking at temperatures from all different kinds of environments. What have they found?

The Earth is getting warmer—global climate change is real. But so are urban heat islands. Human beings have an effect on both global warming and heat islands, but in different ways. Global warming is largely caused by greenhouse gases in the atmosphere. The most abundant greenhouse gases are water vapor,

carbon dioxide, methane, nitrous oxide, and ozone. ***People add greenhouse gases to the air by burning fossil fuels like gasoline and fuel oil. The urban heat island is not caused by greenhouse gases. People affect heat islands mostly through the materials they use for building and paving****.*

From http://chainreactionkids.org/files/issues/6/chreact6_p16_19.pdf - page 18 [bold and italic text highlighted for importance to this lesson]

Extension: Provide students with *Climate Change is Happening* brochure. Have students work with their small groups to come up with a list of things that they each can do to help mitigate (reduce) the effects of global warming. Share these results with the entire class and have students write letters home to their parents or guardians discussing how it is important for everyone to help reduce global warming. Include the class-generated list with the letter.

Explore

Guiding question: "How do plants respond when their habitat heats up?"

Part I: On the Move

Prepare:

- Review lesson on pages 20-28 of the *Natural Inquirer: Climate Change* edition.
- Identify tree/shrub species found on the school property and/or within the immediate neighborhood, selecting native species for your students' research.
- Divide class into small groups of 2-4 each, for the research portion of the lesson.

Present:

Ask: "What is the current geographic distribution of a particular tree/shrub species? What adaptations help them survive in this area?"

Student activity:

- Complete research as indicated (page 26) of the *Natural Inquirer*, selecting from your teacher's list of trees/shrubs that naturally occur within your school community.
- Label one blank map, indicating the range and distribution of your selected species.

Part II: Tree/Shrub Fact File

Prepare:

No advance preparation is needed, as this is a continuation of Part I.

Student activity:

- Read pages 23-24 in the *Natural Inquirer*.
- Using 2 pieces of blank white paper, complete the Tree/Shrub Fact File for your selected species, answering the questions on page 26. [See "First class period" on that page.]
- For the second map, predict and draw the range and distribution for your species as the weather becomes warmer in your area. Consider the landscape around your area and try to find other ecosystems that might support your species.

Closing activity:

- Discuss concepts of mitigation such as assisted migration, seed banking, and plant conservation in a botanical garden.
- Invite a Landscape Ecologist, GIS Analyst, Wildlife Landscape Ecologist (see page 21 in the

Natural Inquirer) or other scientist studying plants in your area to visit your classroom.

Close with a class discussion on how difficult it will be for some plants in your area to survive a warmer climate. [Especially note that species evolve slowly. Thus, a rapidly-changing climate may bring conditions in which individuals cannot adapt quickly enough to survive.]

Extension: The Tree/Shrub Fact File can be continued indefinitely, providing a basis for future scientific inquiry on climate change and other ecological changes within your area.

Explain

Guiding question: "Do plants contribute to the Greenhouse Effect?"

Prepare:

- Review the Carbon Cycle Role-play Lesson Plan (we suggest the following modifications described below).
- Select a large area that can accommodate your entire class. Designate three areas to represent the three Earth spheres and label them: Air, Land, and Water. NOTE: the biosphere – "life" – is found within all three spheres. For the purpose of this activity, it is not a separate sphere but should be considered to be prevalent in all others.
- Gather ping pong balls (each marked with the letter "C" to represent an atom of carbon) and role play cards
- Divide students equally into 7 groups and pre-assign a role to each group. (Refer to the chart in the enclosed lesson.) **Inform the students of the goal of the role-playing activity.**

Present:

- Distribute 2-3 ping pong balls to each group and explain that these represent carbon atoms.
- Tell students they need to look at their role-play card as a group to figure out their role and what they get to do in the role-play activity.
- Tell students that they need to decide as a group how they are going to move their carbon. Their options are listed in the "Options for carbon movement" section on their cards.
- Tell students that they can't give away all their carbon: **they must keep at least one carbon atom**. This is because the carbon cycle doesn't move all the carbon in one place to another place. Rather, carbon exists in all of these things at the same time and only some carbon from each thing moves.
- You might want to conduct one round where students give only one carbon atom to one other group and then conduct a second round where they can split their carbon between different groups, if each group has more than two carbon atoms.

Student activity:

- One at a time, ask each group to give their carbon to another group (or groups).
- Tell students that as they move their carbon, they must say their script lines to explain the carbon movement that they have chosen.
- Run the role-play a number of times, telling students to make different choices about carbon movement each time.
- Consider running the role-play one time with all the groups moving their carbon at the same time. To do this, have one person from each group be the deliverer of carbon and the other group members remain to receive carbon from other groups. Tell students that this is more chaotic - but more realistic - acting out of the carbon cycle, since in the real world carbon moves between all these areas at the same time.

Ask: How are the plants you have researched a part of the carbon cycle? How do they contribute to the greenhouse effect? How will changing climate conditions affect a plant's ability to survive and thrive in its neighborhood?

Ask: If the change in climate is not favorable, what options does the plant have? *Possibilities: 1) Adapt to the new conditions, 2) die out, 3) hope someone moves them to a better environment (assisted migration).*

Students create a visual depiction of the carbon cycle, using their local environment and local plants and animals.

Extension: Students engage in the "Back to the Future" activity (pages 38-49 in *Natural Inquirer*) to understand how dendrochronology contributes to our knowledge of the past. Invite an employee of the Coconino National Forest to bring actual tree cookies to demonstrate the process students have done in class using paper "tree ring" strips. [**Note**: The University of Arizona hosts the Laboratory of Tree-Ring Research lab and museum on campus. Visit http://ltrr.arizona.edu/ for more information.]

Elaborate

Guiding question: "How do scientists know that the climate is changing in my community?"

Prepare:

- Schedule your field trip with The Arboretum staff by contacting their Education Department.
- Schedule buses as per district field trip requirements
- Arrange for requisite number of chaperones
- Obtain required permission slips from every student
- Review safety procedures for field trips

Present:

- Provide copies of "*Integrating climate change and genetic research to restore western landscapes"* and review with students, to acquaint them with the SEGA Project and the role of the Arboretum within that project

Student activity:

- Students explore greenhouses, plant phenology and the SEGA Project at The Arboretum, using their journals to record information that will assist in their final assignment.

Remind students that they, too, are apart of the scientific discovery about climate change within their community via the work they are doing with the phenology research project.

Evaluate

Guiding question: "How do I design for STEM growth?"

Design and build a desktop greenhouse that includes the three spheres of the carbon cycle, a native plant considered endemic to your region, and all the requirements for that plant to survive. [**NOTE:** This will add an engineering element to your classroom practices.]

Prepare:

- Assign each student or teams of students a specific plant that can germinate and start to grow within a small greenhouse. (Ask The Arboretum staff for assistance if necessary).
- Gather any necessary supplies: pots, seeds, soil, plastic wrap, thin strips of wood (for framing),

wood glue. **HINT:** encourage students to consider recyling a plastic bottle or other discarded items that will allow light penetration but will keep moisture inside. This is also a good opportunity to talk about sustainability.

Present and *activity:* [following the steps of the EDP – Engineering Design Process]

- ASK: What will I need to consider if I want to build a desktop greenhouse to help a native plant germinate and start to grow? [*encourage thinking about the three spheres of the carbon cycle, individual needs of the plant and its adaptational strategies*]
- IMAGINE: What would such a desktop greenhouse include? [*consider the basic needs of organisms: food, water, shelter, space when thinking about the design*]
- PLAN: What are three different designs I might use to accomplish this task? Which one do I hink is the best? What will I need to build my design? [*Students select ONE design they will make.* E*ngineers always consider multiple designs – some may be discarded due to cost factors, feasibility of materials, or other considerations – ask students to begin collecting* ***recycled*** *construction materials for their designs*]
- CREATE: Distribute all supplies needed (except seeds). Once the student(s) has selected the optimum design and has identified all supplies needed, allocate those – but save the seeds until the greenhouse is complete. Once the greenhouse is finished to the satisfaction of the student, provide the seed and planting instructions. [*Students should keep a record of all their work: design and materials used, notes about the construction process, placement of the greenhouse for light, specific amount of water added and times it was added, any notes on the phenology of plants as they germinate and grow. These should be scientifically noted: accuracy as to amounts, dates, times, ambient temperatures, etc.*]
- IMPROVE: What did the student(s) learn about their design? Did it function as well as they'd expected? What changes did they need to make in order for the greenhouse to serve the needs of the plant? What might thy do differently next time?

Use the rubric to assess students' results.

Extension: Creating a web page

Prepare:

- Consult with the technology instructor for advice on how students can create a home page for a website detailing their work.
- Assemble any supplies students may need for creating prototypes of a web page.

Present:

Provide any guidance to students that may be necessary for this culminating activity. Allow students the opportunity to be as creative as possible as they reflect on this guiding question and pull together what they learned about the following:

1. What is the greenhouse effect? The Albedo Effect?
2. How does a greenhouse differ from planet Earth?
3. What adaptations of trees help them survive in this area? What predictions might we make about their distribution if the area becomes warmer and drier?
4. How are trees an integral part of the carbon cycle?
5. What should people in my community know about our area's native trees and their future?

Student activity:

Small groups create a home page for a website that will share their knowledge with the community.

[**NOTE:** You may opt to assign a different website page to each group: one will create the home/landing page, another one for the Greenhouse Effect or the Albedo Effect, etc. While this may take additonal time, it may provide a more comprehensive demonstration of student learning.]

Use the rubric to assess students' products.

Closure:

Ask:

- "How are gardens, greenhouses and global warming connected? "
- "If you came back to revisit this are 500 years from now, and climate change has continued at its current rate, what plants might you expect to find here?"

Standards addressed do not include those for the continuation of the phenology project. (See grade 6.)

Standards Addressed in Each Lesson

(Refer to "Overview" for complete text of all standards cited. ACCR is the Arizona College and Career Readiness Standards, aka "Common Core".)

ENGAGE – Science S1C2PO1, PO4, PO5 S1C3PO5 S1C4PO1, PO3, PO5 S2C2PO3	**ENGAGE – ACCR** 6-8.RST.1 6-8.RST.4 6-8.RST.7	**ENGAGE – Math** 7.MP.5 7.MP.6	**ENGAGE – Technology** S6C1PO3
EXPLORE – Science S1C2PO2 S1C2PO1, PO5 S1C3PO1, PO2, PO4, PO5, PO7 S1C4PO3, PO5 S2C1PO4 S2C2PO3 S4C3PO3, PO5	**EXPLORE – ACCR** 6-8.RST.1 6-8.RST.3 6-8.RST.4 6-8.RST.7	**EXPLORE – Math** 7.SP.A.1 7.MP.2 7.MP.3 7.MP.5 7.MP.6	**EXPLORE – Technology** S1C1PO1 S1C3PO2 S2C2PO1
EXPLAIN – Science S1C1PO2 S1C3PO2 S2C2PO3	**EXPLAIN – ACCR** 6-8.RST.1 6-8.RST.4 6-8.RST.7	**EXPLAIN – Math** None	**EXPLAIN – Technology** S1C1PO1
ELABORATE – Science S1C2PO1 and PO5 S1C3PO7 S2C1PO4 S2C2PO3 S3C1PO2 S4C3PO2 S4C3PO3 and PO5	**ELABORATE – ACCR** 6-8.RST.4	**ELABORATE – Math** 7.SP.A.1 7.MP.2 7.MP.3	**ELABORATE – Tech.** S1C1PO1
EVALUATE – Science* S1C1PO2 S1C3PO1, PO2, PO4, PO5,PO7 S1C4PO4 and PO5 S2C1PO4 S2C2PO3 S3C1PO1, PO2, PO3 S3C2PO1 S4C3PO2 S4C3PO4,PO5,PO6	**EVALUATE – ACCR*** 6-8.RST.3 6-8.RST.7	**EVALUATE – Math*** 7.MP.2 7.MP.5 7.MP.6	**EVALUATE – Tech.*** S1C3PO2 S1C4PO1 S2C2PO1 S6C1PO3

*Standards addressed in Evaluate are dependent upon the option selected (website or greenhouse).

Science

Inquiry

S1C1PO2. Select appropriate resources for background information related to a question, for use in the design of a controlled investigation.

S1C2PO1. Demonstrate safe behavior and appropriate procedures (e.g., use and care of technology, materials, organisms) in all science inquiry.

S1C2PO 4. Perform measurements using appropriate scientific tools (e.g., balances, microscopes, probes, micrometers).

S1C2PO 5. Keep a record of observations, notes, sketches, questions, and ideas using tools such as written and/or computer logs.

S1C3PO1. Analyze data obtained in a scientific investigation to identify trends.

S1C3PO2. Form a logical argument about a correlation between variables or sequence of events (e.g., construct a cause-and-effect chain that explains a sequence of events).

S1C3PO4. Determine validity and reliability of results of an investigation.

S1C3PO5. Formulate a conclusion based on data analysis.

S1C3PO7. Formulate new questions based on the results of a previous investigation.

S1C4PO1. Choose an appropriate graphic representation for collected data:

- line graph
- double bar graph
- stem and leaf plot
- histogram

S1C4PO3. Communicate the results of an investigation with appropriate use of qualitative and quantitative information.

S1C4PO4. Write clear, step-by-step instructions for following procedures (without the use of personal pronouns).

S1C4PO5. Communicate the results and conclusion of the investigation.

History and Nature of Science

S2C1PO4. Analyze the use of technology in science-related careers.

S2C2PO3. Apply the following scientific processes to other problem solving or decision making situations:

- Observing
- Questioning
- Communicating
- Organizing data
- Predicting
- Inferring
- Generating hypothesis
- Identifying variables

NOTE: Classifying is a part of this PO but is not addressed in this lesson.

Science in Personal and Social Perspectives

S3C1PO1. Analyze environmental risks (e.g., pollution, destruction of habitat) caused by human interaction with biological or geological systems.

S3C1PO2. Analyze environmental benefits of the following human interactions with biological or geological systems:

- reforestation
- habitat restoration

Note: construction of dams is part of this PO but is not addressed in tis lesson.

S3C1PO3. Propose possible solutions to address the environmental risks in biological or geological systems.

S3C2PO1. Propose viable methods of responding to an identified need or problem.

Life Science

S4C3PO2. Explain how organisms obtain and use resources to develop and thrive in:

- niches

NOTE: Predator/prey relationships are a part of this PO but are not addressed in this lesson.

S4C3PO3. Analyze the interactions of living organisms with their ecosystems:

- limiting factors
- carrying capacity

S4C3PO4. Evaluate data related to problems associated with population growth (e.g., overgrazing, forest management, invasion of non-native species) and the possible solutions.

S4C3PO5. Predict how environmental factors (e.g., floods, droughts, temperature changes) affect survival rates in living organisms.

S4C3PO6. Create a model of the interactions of living organisms within an ecosystem.

AZ College and Career Readiness Standards - ELA

Key Ideas and Details

- Cite specific textual evidence to support analysis of science and technical texts. **(6-8.RST.1)**
- Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. **(6-8.RST.3)**

Craft and Structure

- Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 6–8 texts and topics.* **(6-8.RST.4)**

Integration of Knowledge and Ideas

- Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). **(6-8.RST.7)**

AZ College and Career Readiness Standards – Math

Statistics and Probability (SP)

Use random sampling to draw inferences about a population.

7.SP.A.1. Understand that statistics can be used to gain information about a population by examining a sample of the population; generalizations about a population from a sample are valid only if the sample is representative of that population. Understand that random sampling tends to produce representative samples and support valid inferences.

Investigate chance processes and develop, use, and evaluate probability models.

7.SP.C.6. Approximate the probability of a chance event by collecting data on the chance process that produces it and observing its long-run relative frequency, and predict the approximate relative frequency given the probability.

Standards for Mathematical Practice (MP)

7.MP.1. Make sense of problems and persevere in solving them.

7.MP.2. Reason abstractly and quantitatively.

7.MP.3. Construct viable arguments and critique the reasoning of others.

7.MP.5. Use appropriate tools strategically.

7.MP.6. Attend to precision.

Technology

Creativity and Innovation

S1C1PO1 Analyze and evaluate information to generate new ideas, processes or products.

S1C3PO2 Ask questions and investigate a problem from different perspectives and formulate inferences from known facts.

S1C4PO1 Create innovative products or projects using digital tools to express original ideas.

Communication and Collaboration

S2C2PO1 Collaborate and communicate with peers, experts, or others employing a variety of digital tools to share findings and/or publish.

Technology Operations and Concepts

S6C1PO3 Choose technology applications appropriate for the audience and task.

An Island in the Sun

Is the whole world getting hot, or are we just making it hot in the places we live? How would you decide?

BY DIANE BOUDREAU

When you think about islands, you probably think about Hawaii or Jamaica. You probably don't think about Phoenix, Arizona. Phoenix has all the sand of a beachside resort, but it is not surrounded by water. Still, Phoenix is a type of island. Scientists call it an "urban heat island."

Phoenix is a city surrounded by desert and farmland. That's the "urban" part of the island. But the city is also hotter than the area around it. It is an island of heat.

How can this be so? Cities are made of buildings, roads, and parking lots. These structures absorb more heat from the sun than things like plants or dirt. They also hold onto the heat longer. When the desert cools down at night, the city stays pretty hot. You can often feel the heat radiating off of walls and pavement.

With summer temperatures well over 100 degrees Fahrenheit, people in Phoenix don't need more heat! Hotter weather means people use more energy and more water. These are two resources we need to conserve.

Tony Brazel is a climatologist at Arizona State University. He has been studying the Phoenix heat island for more than 20 years. He looks at the difference between city temperatures and rural temperatures.

This photo shows Phoenix as seen from the orbiting Space Shuttle. Can you see the difference between urban and rural areas?

[Thought question:]
Why would higher temperatures in Arizona make people use more electricity and more water?

This difference is called the "heat island magnitude." Brazel also studies what causes this difference, and how we can reduce it. "We've found it can be 12 to 15 degrees Fahrenheit higher in the city than in rural areas. On one night we measured a 22-degree difference between the Southeast Valley agricultural area and Sky Harbor Airport," Brazel says.

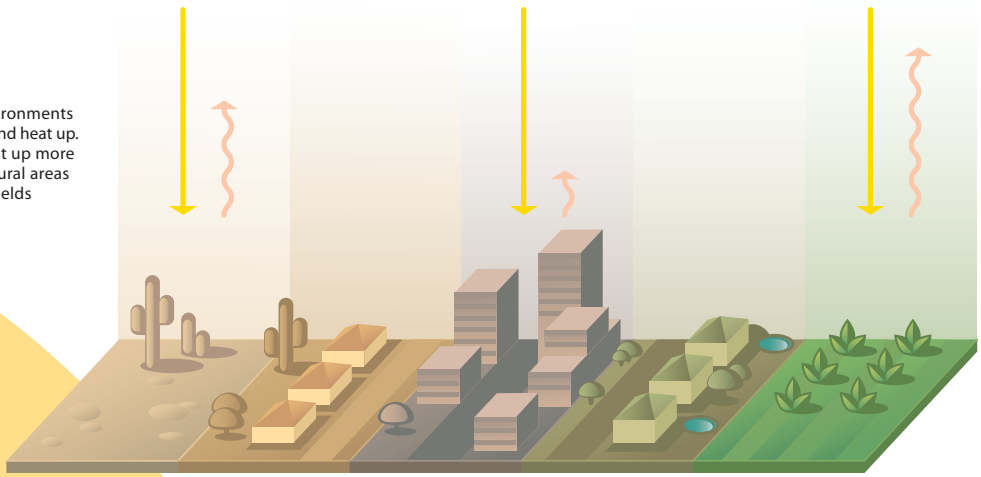
Agricultural areas are cooler than natural desert, Brazel says. This is because farms have a lot of water and plants. When water evaporates, it lowers the temperature of whatever is around it. For example, your body cools off when your sweat evaporates.

Some of the landscape water evaporates directly. Some of it evaporates through the leaves of plants in a process called transpiration. Plants also provide shade that further cools the ground. "You get a larger heat island magnitude if you compare the urban site to an agricultural area," says Brazel. "There's a smaller effect if you compare it to the natural desert."

Even within the city, there are temperature differences. Some neighborhoods are just plain hotter than others. Brazel and other ASU scientists are conducting a study to find out which neighborhoods and built-up areas are hottest, and why. Working with ASU's Decision Center for a Desert City, the scientists are looking at water use and nighttime temperatures. They are using a computer model and satellite surface temperatures of different neighborhoods—some quite dry, others with a lot of greenery. "The key is what we call impervious surfaces—roads, parking lots, buildings. Asphalt and concrete are heat-retaining materials that store energy and at night are still warm," says Brazel. >>>

Swamp cooler vs. air conditioner?

"Swamp cooler" is the popular name for a device known as an evaporative cooler. The device uses evaporation to cool a home. Evaporation also makes the air inside more humid. In an arid climate—such as Arizona's Sonoran Desert—added humidity can make for a more comfortable environment inside a home. However, when the summer rains begin, the air in the desert becomes very humid. Evaporation is no longer an efficient source of cooling. Swamp coolers no longer work well. To keep the inside environment comfortable, you need an air conditioner. This device uses a refrigeration cycle to cool the air inside a home. Hot humid air is blown over a chilled "condenser." This cools the air and also causes the humidity to condense, drying the air. The air that enters the home is cool and "dehumidified." In Arizona, the summer weather reports include the "evaporative cooling index." This is similar to the heat index. The evaporative cooling index measures how cold a swamp cooler will make your house depending on the relative humidity.



Sunlight beams down evenly on all the different environments of the desert. Some areas capture more of the energy and heat up. Urban areas with lots of pavement and buildings heat up more than suburban areas with houses and trees. Agricultural areas may heat up less than the open desert because the fields evaporate water, which carries off some heat.

Global warming or heat island?

Global warming and urban heat islands are both examples of how human beings can affect the weather. But they are not the same thing. Global warming is the average temperature change for the whole world. Urban heat islands are limited to individual cities.

In the 1990s, people used temperatures taken in cities to support the theory of global warming. Because of this, some scientists believed that global warming wasn't really happening. They said that the rising temperatures were actually an effect of urban heat islands, but weren't happening on a global level.

Now, scientists are looking at temperatures from all different kinds of environments. What have they found? The Earth is getting warmer—global climate change is real. But so are urban heat islands.

Human beings have an effect on both global warming and heat islands, but in different ways. Global warming is largely caused by greenhouse gases in the atmosphere. The most abundant greenhouse gases are water vapor, carbon dioxide, methane, nitrous oxide, and ozone. People add greenhouse gases to the air by burning fossil fuels like gasoline and fuel oil.

The urban heat island is not caused by greenhouse gases. People affect heat islands mostly through the materials they use for building and paving.

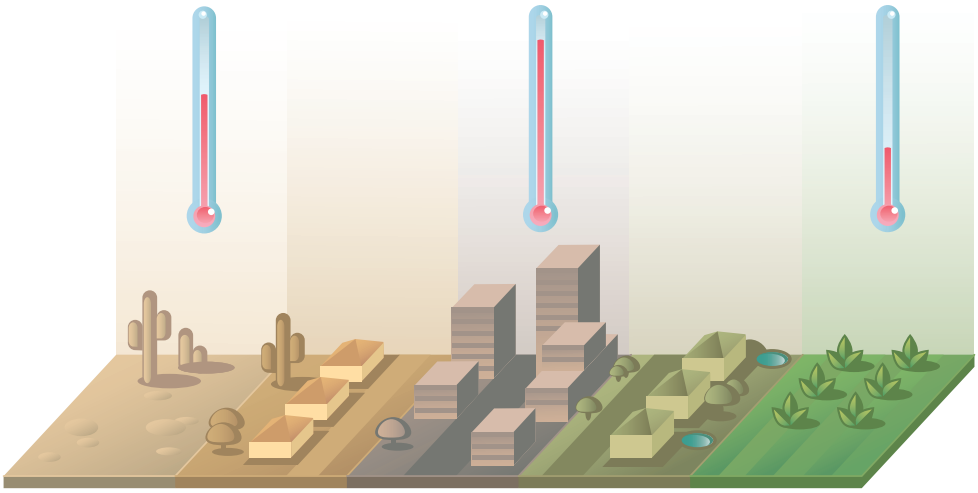
On the other end of the spectrum is vegetation—good old green plants. The sun's energy goes into evaporating the water that these plants receive, not into the ground. The researchers are finding out that neighborhoods with more plants and more water (such as swimming pools) are cooler than neighborhoods without these features. "This creates a dilemma," says Brazel. "On the one hand, we are a desert with limited water resources and we want to conserve water. On the other hand, we have a heat island problem, and using more water may create a cooler environment."

So far, the findings suggest that you can get significant cooling effects from adding a small amount of vegetation to areas that don't have much. But if you go into a neighborhood that already has a lot of vegetation and add even more, you don't get a very big boost in cooling. In fact, you can remove some of the plants from these areas without making them hotter.

Phoenix is not the only urban heat island in the world. Brazel says that all of the world's largest cities—such as Mexico City, Tokyo, and Los Angeles—have a major heat island effect. "What surprises people is that even small places can have heat islands. Even a shopping center can be substantive. When you change the surface, you change the temperature virtually overnight," says Brazel.

Adding plants is not the only way to lower temperatures in cities. There are other ways to cool the heat island. Choosing building materials that don't absorb a lot of heat is one way. For instance, buildings could use light-colored, cooling roof materials. And cities could pave streets and parking lots with less heat-absorbent paving materials.

Researchers with ASU's National Center for Excellence in SMART Innovations are studying how new paving materials can help the environment. They paved an ASU parking lot with pervious pavement. It allows water and air to pass through it. Pervious pavement absorbs less heat than regular pavement. It also reduces water pollution by eliminating runoff, and improves safety by preventing water from pooling on the surface.



The scientists have installed heat and moisture sensors on the parking lot. They are comparing the data with information from regular parking lots to find out how much effect the new pavement has.

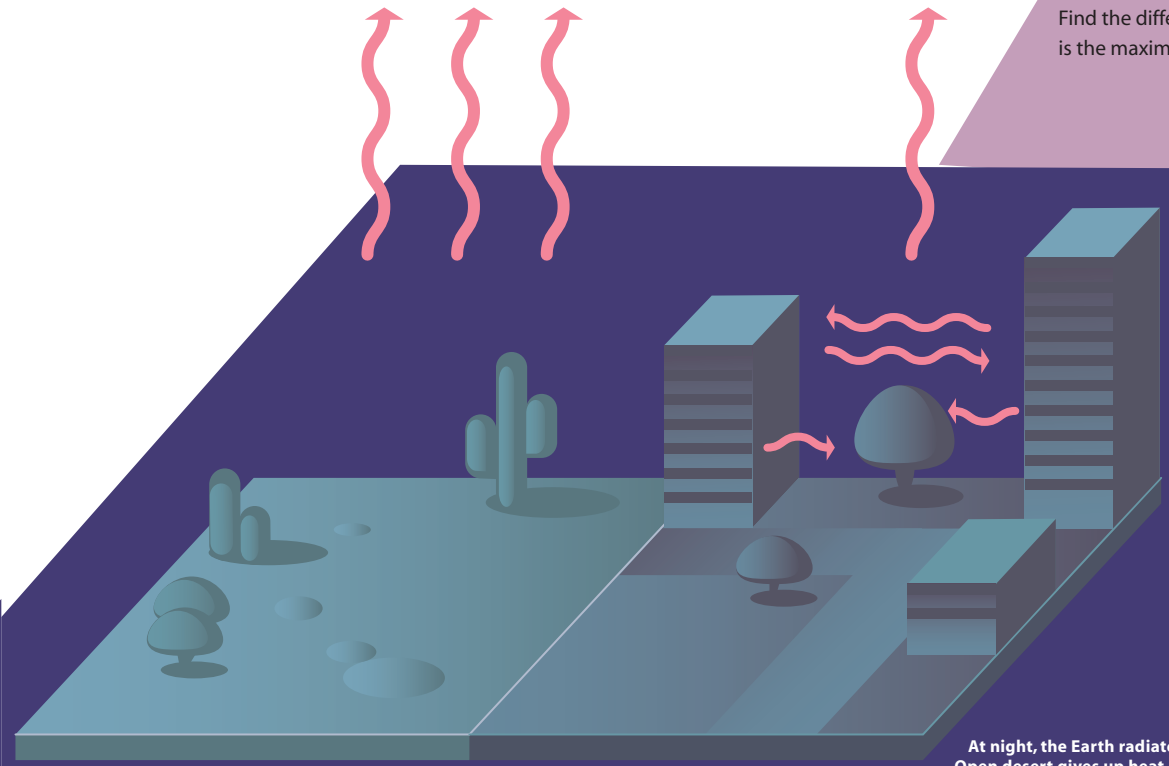
The way buildings are arranged can also have an effect on heat islands. Brazel talks about "urban canyons," created when you place tall buildings along narrow streets. The buildings provide shade and create cooling wind patterns. "The city of Phoenix was planned long ago," says Brazel. "It has wide streets with few trees. Now, ASU and the city are trying to make it pedestrian-friendly. We're trying to create a sustainable city."

Defining the heat island—two ways to do so

How do you know when a city is an urban heat island? ASU climatologist Tony Brazel says there are two general ways to define a heat island.

The average heat island: Find climate records for a weather station in the city and one outside the city. Write down the lowest and highest temperature from each station for each day in a month. Then find the average (mean) of all the high city temperatures, all the low city temperatures, all the high rural temperatures, and all the low rural temperatures. The difference between the city and rural temperatures is the average heat island.

The maximum heat island: Many things can affect a city's temperature besides the heat island effect. Wind, clouds, and rain all confuse the issue. When people want to know what effect the city alone has on temperature, they measure the maximum heat island. Choose a calm, sunny day with no wind, no clouds, and low humidity. Measure the temperature at a rural station and at the densest, hottest part of the city. Find the difference between the two. This is the maximum heat island.



At night, the Earth radiates heat back into the atmosphere. Open desert gives up heat quickly. Buildings and pavements in the urban center give up less heat, because radiated heat given off by one structure is trapped by another.

Carbon Cycle Role-Play

GRADE LEVELS	3rd-8th; California Content Standards for 3rd, 4th, 5th, 6th, and 8th
SUBJECTS	Life Sciences, Earth Sciences, Physical Sciences
DURATION	Preparation: 10 minutes Activity: 30-45 minutes
SETTING	Large space: schoolyard, cafeteria, or classroom

Objectives

In this activity, students will:

1. learn that there is a finite amount of carbon on earth.
2. learn that carbon moves around in the environment, from one place to another.

Materials

ping pong balls (at least 14)
permanent marker
chalk
Carbon Cycle Role-Play Cards (provided)

Vocabulary

- carbon: a naturally abundant, nonmetallic element that occurs in all organic compounds and can be found in all known forms of life
- carbon dioxide: a colorless, odorless gas that is present in the atmosphere, formed during respiration, produced during organic decomposition, used by plants in photosynthesis, and formed when any fuel containing carbon is burned
- atmosphere: the mixture of gases surrounding the earth, held in place by gravity
- lithosphere: rigid, rocky outer layer of the earth
- hydrosphere: all of the earth's water, including surface water (water in oceans, lakes, and rivers), groundwater (water in soil and beneath the earth's surface), snowcover, ice, and water in the atmosphere, including water vapor
- biosphere: the parts of the land, sea, and atmosphere in which organisms are able to live
- algae: a general term for microscopic or larger aquatic plants. They differ from trees, bushes, and other flowering plants because they lack true roots, stems, and leaves.
- photosynthesis: the process by which green plants, algae, diatoms, and certain forms of bacteria make carbohydrates from carbon dioxide and water, using energy captured from sunlight
- respiration: processes that take place in the cells and tissues during which energy is released and carbon dioxide is produced

Teacher Background

Carbon is an extremely common element on earth and can be found in all four major spheres of the planet: biosphere, atmosphere, hydrosphere, and lithosphere. Carbon is found in both the living and non-living parts of the planet, as a component in organisms, atmospheric gases, water, and rocks. The carbon contained in any of the planet's spheres does not remain there forever. Instead, it moves from one sphere to another in an ongoing process known as the carbon cycle. The carbon cycle is extremely important on earth as it influences crucial life processes such as photosynthesis and respiration, contributes to fossil fuel formation, and impacts the earth's climate.

Besides the relatively small additions of carbon from meteorites, the amount of carbon on the planet is stable. But, the amount of carbon in any given sphere of the planet can increase or decrease depending on the fluctuations of the carbon cycle. The cycle can be thought of in terms of reservoirs (places where carbon is stored) and flows (the movement between reservoirs). The atmosphere, the biosphere, the hydrosphere, and the lithosphere are the reservoirs and the processes by which carbon moves from one reservoir to another are the flows. Although carbon is extremely common on earth, pure carbon is not common. Rather, carbon is usually bound to other elements in compounds. Thus, when carbon moves or cycles, it is usually doing so within compounds, such as carbon dioxide and methane.

The many processes that move carbon from one place to another happen on different time scales. Some of them happen on short time scales, such as photosynthesis, which moves carbon from the atmosphere into the biosphere as plants extract carbon dioxide from the atmosphere. Some carbon cycle processes happen over much longer time scales. For example, in the ocean, organisms with calcium carbonate skeletons and shells die and some of their remains, those that don't decompose, sink towards the ocean floor. Upon reaching the ocean floor, the carbon that was stored in their bodies becomes part of the carbon-rich sediment and is eventually carried along, via plate tectonic movement, to subduction zones where it is converted into metamorphic rock. These two examples show the extreme variety of processes that take place in the carbon cycle.

In general, the short-term carbon cycle encompasses photosynthesis, respiration, and predator-prey transfer of carbon. On land, there is a flow of carbon from the atmosphere to plants with photosynthesis and then a flow back to the atmosphere with plant and animal respiration and decomposition. For aquatic plants, photosynthesis involves taking carbon dioxide dissolved in the water around them and respiration and decomposition put carbon dioxide back into the water. In addition to moving between plants and the atmosphere or the water, carbon dioxide is also constantly moving between the atmosphere and water via diffusion. The long-term carbon cycle encompasses more of the lithospheric processes. It involves the weathering and erosion of carbon-containing rocks, the accumulation of carbon-rich plant and animal material in sediments, and the slow movement of those sediments through the rock cycle.

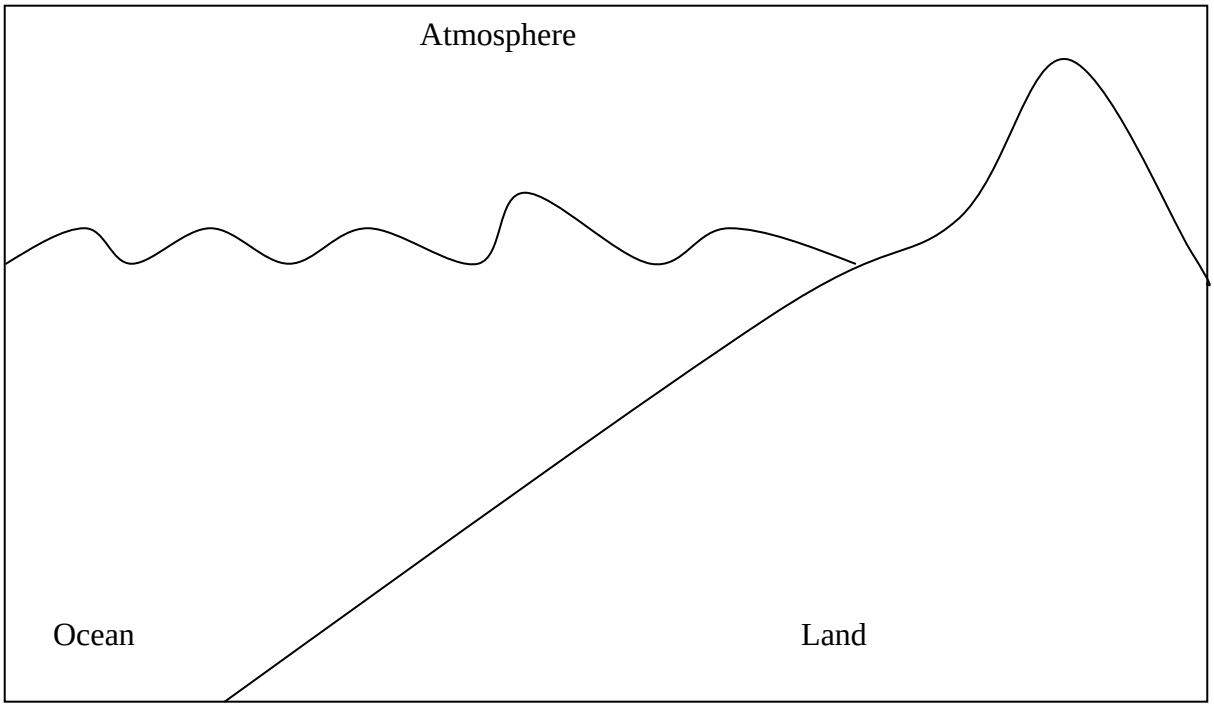
There are natural fluctuations in the carbon cycle, but humans have been changing the carbon flows on earth at an unnatural rate. The major human-induced changes result in increased carbon dioxide in the atmosphere. The largest source of this change is burning fossil fuels, but other actions such as deforestation and cement manufacturing also contribute to this change in the carbon cycle. Because carbon dioxide and methane are greenhouse gases that help to control the temperature of the planet, the human-induced increase in atmospheric carbon levels is resulting in a host of climatic changes on our planet. As discussed above, the natural carbon cycle is important to learn because it is crucial to many of earth's processes, but an understanding of the carbon cycle is especially important at this time in human history because of the dramatic and consequential alterations we are making to the cycle.

The entire carbon cycle is composed of even more specific flows between the atmosphere, biosphere, hydrosphere, and lithosphere than those discussed here. This role-play teaches an age-appropriate version of the carbon cycle. Although there are more specific details involved in the earth's complicated carbon cycle, this version will highlight some of the most important components and will teach students the overall concept that carbon is finite and moves through the different spheres of the planet. Before teaching the Carbon Cycle Role-Play, read through the table in the procedure section to get a better understanding of the specific flows your students will be learning. For more detailed carbon cycle information investigate the resources and references listed at the end of the lesson plan.

Activity

Preparation

1. Collect 14-28 ping pong balls.
2. Write the chemical symbol for carbon (C) on each ping pong ball with a permanent marker.
3. Print the role-play cards. Make sure that they are double-sided.
4. Designate a large open space for this activity. If working outside, use chalk to designate a large rectangular area. Then, use chalk to divide the space into three regions, one for the ocean, one for the land, and one for the atmosphere as shown below. Another option is to draw a picture on the board of the three regions shown below and then designate different areas of the classroom to represent the ocean, the land, and the atmosphere.



Introduction

We suggest using the "What Contains Carbon?" activity as an introduction to the "Carbon Cycle Role-Play." Review with your students that carbon is a common element on earth. Have students recall some of the things in their daily lives that contain carbon. Make a list of these items on the board. Then tell your students that the carbon contained in any one thing doesn't stay there forever. The carbon atoms move from one thing to another in what is called the carbon cycle. Parts of the carbon cycle happen very quickly, like when plants take in carbon dioxide from the atmosphere for photosynthesis. But, other parts of the carbon cycle happen very slowly. Tell students that in this activity, they will learn how carbon moves from one place to another, by performing a carbon cycle role-play.

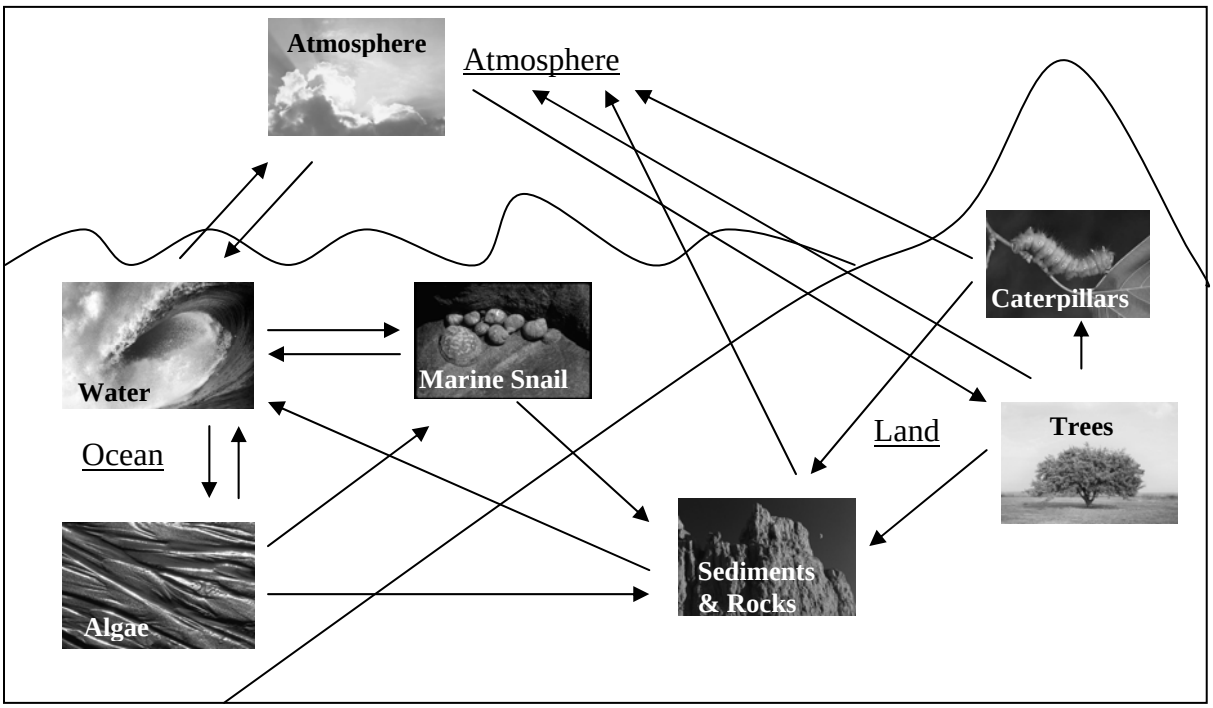
Procedure

1. Divide students evenly into 7 groups. Each group will be a team of actors that will play a certain part of the carbon cycle. The groups are listed in the table below.
2. Distribute the appropriate role-play card to each group.
3. Distribute 2-4 ping pong balls to each group and explain that these represent carbon atoms.
4. Tell students that they need to look at their role-play card as a group to figure out their role and what they get to do in the role-play activity.
5. Tell students that they need to decide as a group how they are going to move their carbon. Their options are listed in the "Options for carbon movement" section on their cards.
6. Tell students that they can't give away all their carbon: they must keep at least one carbon atom. This is because the carbon cycle doesn't move all the carbon in one place to another place. Rather, carbon exists in all of these things at the same time and only some carbon from each thing moves.
7. You might want to conduct one round where students give only one carbon atom to one other group and then conduct a second round where they can split their carbon between different groups, if each group has more than two carbon atoms.
8. One at a time, ask each group to give their carbon to another group (or groups).
9. Tell students that as they move their carbon, they must say their script lines to explain the carbon movement that they have chosen.
10. Run the role-play a number of times, telling students to make different choices about carbon movement each time.
11. Consider running the role-play one time with all the groups moving their carbon at the same time. To do this, have one person from each group be the deliverer of carbon and the other group members remain to receive carbon from other groups. Tell students that this is a more chaotic, but more realistic acting out of the carbon cycle, since in the real world carbon moves between all these areas at the same time.

NAME of GROUP	Options for CARBON FLOWS	Explanation for each CARBON FLOW	SCRIPT LINES
Atmosphere	1. water 2. trees	1. Carbon dioxide from the atmosphere diffuses and dissolves into water. 2. Carbon dioxide is taken up by land plants to perform photosynthesis.	1. I am giving carbon dioxide gas to water. It will dissolve in water. 2. I am giving carbon dioxide gas to trees to use for photosynthesis.

Water	1. algae 2. marine snails 3. atmosphere	1. Aquatic plants use carbon dioxide from the water to perform photosynthesis. 2. Some marine organisms take carbon from the water to build their skeletons and shells. 3. Carbon dioxide can diffuse back into the atmosphere.	1. I am giving dissolved carbon dioxide to algae for photosynthesis. 2. I am giving carbon to marine snails to help build their shells. 3. I am taking dissolved carbon dioxide and putting it back in the atmosphere as carbon dioxide gas.
Algae (Aquatic Plants)	1. water 2. sediments and rocks 3.marine snails	1. Cellular respiration and decomposition put carbon back into the water. 2. Carbon from dead plants can be incorporated into sediments. 3. Animals consume aquatic plants and use it as energy or store it in tissues.	1. I am giving carbon to water when I die and decompose and when I perform respiration. 2. I am giving carbon to sediments and rocks because after I die, some of the carbon in my structures is laid down in sediments, which can turn to rock. 3. I am giving carbon to marine snails because they use their mouths to scrap me off the rocks and eat me.
Marine Snails (Aquatic Animals)	1. water 2. sediments and rocks	1. Respiration and decomposition put carbon back into the water. 2. Carbon from dead animals can be incorporated into sediments on the ocean floor and can eventually become sedimentary and metamorphic rocks.	1. I am giving carbon to water when I perform respiration and when I die and decompose. 2. I am giving carbon to sediments and rocks because when I die my hard, carbon-containing shell sinks to the ocean floor and becomes part of the sediment, which can then become rock.
Sediments and Rocks	1. water 2. volcano to atmosphere	1. Weathering and erosion of rocks deposits carbon in rivers and oceans. 2. Volcanic eruptions spew carbon-containing gases into the atmosphere.	1. I am giving carbon to water because when I am weathered and eroded, my carbon flows into water. 2. I am giving carbon to the atmosphere in a quick fury because volcanoes erupt and put carbon from rocks back into the atmosphere.
Trees (Land Plants)	1. atmosphere 2. sediments and rocks 3. caterpillars	1. Cellular respiration and decomposition put carbon back into the atmosphere. 2. Carbon from dead trees can be buried and incorporated into sediments. 3. Plants are consumed by animals that use carbon for energy or store it in tissue.	1. I am giving carbon to the atmosphere when I perform respiration and when I die and decompose. 2. I am giving carbon to sediments and rocks because when I die, I can be buried in sediments and slowly become part of the rocks. 3. I am giving carbon to caterpillars because you have eaten me and will use my carbon for energy or to make your body's structures.
Caterpillars (Land Animals)	1. atmosphere 2. sediments and rocks	1. Respiration and the decomposition of dead animals put carbon back into the atmosphere. 2. Carbon from dead animals can be buried and incorporated into sediments.	1. I am giving carbon to the atmosphere because when I breathe I release carbon dioxide to the atmosphere. 2. I am giving carbon to sediments and rocks because when I die I can be buried and some of the carbon in my body can become part of sediments.

Either as a pre-teach tool, or as a review after the role-play activity, work with your students to draw all the carbon-related interactions on the board. Use the picture below as a template.



Wrap-Up

Tell students that they just acted out the carbon cycle without human involvement. But, humans greatly influence the carbon cycle with some of their activities. Pull a few students aside and have them be the humans. Ask them to move the carbon in the appropriate manner for each of the following human alterations. First have students guess what the movement will be and then help them make the appropriate movement.

- Humans extract and burn fossil fuels for energy – carbon moves from the sediments and rocks where fossil fuels are buried into the atmosphere.
- Humans cut and burn trees to use land for farming, ranching, or building – carbon moves from the land plants into the atmosphere.

Aid students in understanding these human alterations. Explain that burning fossil fuels takes carbon from sediments and rocks where fossil fuels are buried and puts it into the atmosphere because when fossil fuels are burned they release carbon-containing gases. Explain that cutting and burning trees takes carbon from the land plants and puts it into the atmosphere because when trees are burned, the carbon that was stored in their structures is released as carbon-containing gases. Explain that humans have not created more carbon on earth, but that we move carbon from one place to another more quickly than would naturally happen and that this has consequences for the climate of the planet.

Extensions

- Trace the journeys of a few carbon atoms: Use only one carbon atom (ping pong ball) and start it with one group. Each group that gets the atom makes a decision about where it goes next. Assign one student to write the journey on the board or a piece of paper. Do this multiple times so that you can compare the journeys of several individual atoms. Then, look at the different journeys different carbon atoms can take through the spheres. Explain that the carbon cycle does not move in one direction, but moves in lots of different directions at the same time.
- Adapt this activity to be more advanced by having students design their own role-play exercise.
- Follow this activity with the "Carbon Cycle Poster" activity, which serves as a form of assessment.

Resources

NASA, earth observatory. *The carbon cycle.* Retrieved on January 14, 2008 from http://earthobservatory.nasa.gov/Library/CarbonCycle/carbon_cycle2.html

Houghton, R. (2007). *Understanding the global carbon cycle*. Retrieved on March 26, 2008 from http://www.whrc.org/carbon/index.htm

References

Mackenzie, F.T. (2003). *Our Changing Planet: An Introduction to Earth Science and Global Environmental Change.* Upper Saddle River, NJ: Prentice Hall.

NASA, earth observatory. *The carbon cycle.* Retrieved on January 14, 2008 from http://earthobservatory.nasa.gov/Library/CarbonCycle/carbon_cycle2.html

Tarbuck, E.J., & Lutgens, F.K. (2002). *Earth: An Introduction to Physical Geology.* Upper Saddle River, NJ: Prentice Hall.

Correlated California Content Standards

Grade Three

Physical Sciences

1a. Students know energy comes from the Sun to Earth in the form of light

Life Sciences

3c. Students know living things cause changes in the environment in which they live: some of these changes are detrimental to the organism and some are beneficial

Grade Four

Life Sciences

2c. Students know decomposers, including many fungi, insects, and microorganisms, recycle matter from dead plants and animals

Earth Sciences

5a. Students know some changes in the earth are due to slow processes, such as erosion, and some changes are due to rapid processes, such as landslides, volcanic eruptions, and earthquakes.

Grade Five

Physical Sciences

1a. Students know that during chemical reactions the atoms in the reactants rearrange to form products with different properties.

1b. Students know all matter is made of atoms, which may combine to form molecules.

1g. Students know properties of solid, liquid, and gaseous substances, such as sugar (C6HO6), water (H2O), helium (He), oxygen (O2), nitrogen (N2), and carbon dioxide (CO2).

1h. Students know living organisms and most materials are composed of just a few elements.

Life Sciences

2f. Students know plants use carbon dioxide (CO_2) and energy from sunlight to build molecules of sugar and release oxygen.

2g. Students know plant and animal cells break down sugar to obtain energy, a process resulting in carbon dioxide (CO_2) and water (respiration).

Grade Six

Life Sciences

5a. Students know energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis and then from organism to organism through food webs.

5b. Students know that matter is transferred over time from one organism to others in the food web and between organisms and the physical environment.

Grade Eight

Life Sciences

6a. Students know carbon, because of its ability to combine in many ways with itself and other elements, has a central role in the chemistry of living organisms.

6b. Students know that living organisms are made of molecules consisting largely of carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur.

Carbon Cycle Role-Play Card

ATMOSPHERE

Group description:

You are the atmosphere, the gases that surround our planet. You have carbon in the form of carbon dioxide and other gas. Carbon dioxide is a greenhouse gas, which helps to maintain the temperature of the planet.

Stage position:

In the atmosphere.

Options for carbon movement:

1. water
2. trees

Script lines:

I am the atmosphere and

1. I am giving carbon dioxide gas to water. It will dissolve in water.

2. I am giving carbon dioxide gas to trees to use for photosynthesis.

Carbon Cycle Role-Play Card

ATMOSPHERE

Carbon Cycle Role-Play Card

WATER

Group description:

You are the water on our planet. Carbon dioxide gas dissolves in water and allows algae to perform photosynthesis and helps marine snails and other animals make their shells and skeletons.

Stage position:

In the ocean.

Options for carbon movement:

1. algae
2. marine snails
3. atmosphere

Script lines:

I am water and

1. I am giving dissolved carbon dioxide to algae for photosynthesis.

2. I am giving carbon to marine snails to help build their shells.

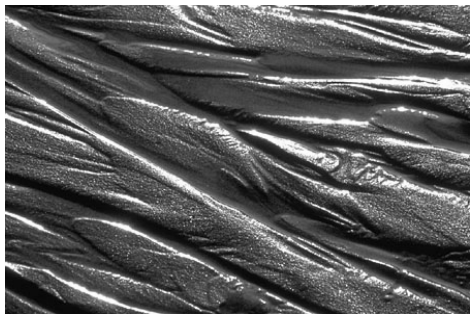
3. I am taking dissolved carbon dioxide and putting it back in the atmosphere as carbon dioxide gas.

Carbon Cycle Role-Play Card

WATER

Carbon Cycle Role-Play Card

ALGAE



Group description:

You are algae, plants that live in water and don't have roots, stems, or leaves like trees and bushes. You get carbon dioxide from the water around you to perform photosynthesis.

Stage position:

In the ocean.

Options for carbon movement:

1. water
2. sediments and rocks
3. marine snails

Script lines:

I am algae and

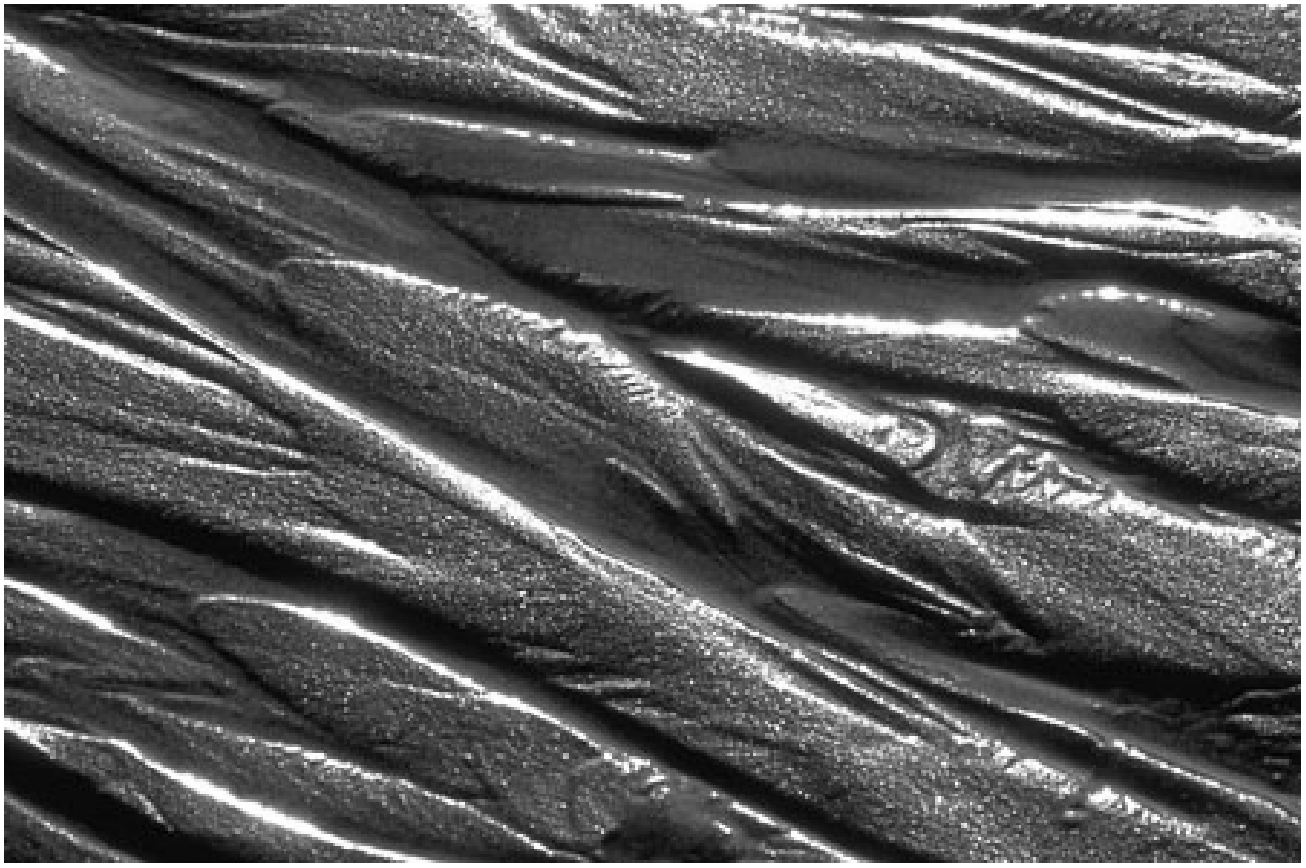
1. I am giving carbon to water when I die and decompose and when I perform respiration.

2. I am giving carbon to sediments and rocks because after I die, some of the carbon in my structures is laid down in sediments, which can turn to rock.

3. I am giving carbon to marine snails because they use their mouths to scrap me off the rocks and eat me.

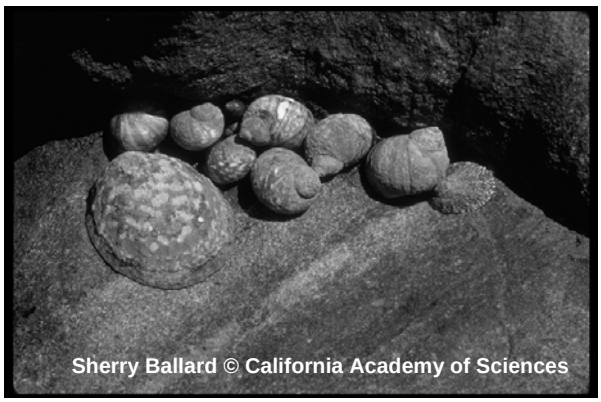
Carbon Cycle Role-Play Card

ALGAE



Carbon Cycle Role-Play Card

MARINE SNAIL



Group description:

You are limpets, a kind of marine snail that lives in the ocean and feeds on algae. You have carbon in your body and your shell.

Stage position:

In the ocean.

Options for carbon movement:

1. water
2. sediments and rocks

Script lines:

I am a marine snail and

1. I am giving carbon to water when I perform respiration and when I die and decompose.

2. I am giving carbon to sediments and rocks because when I die my hard, carbon-containing shell sinks to the ocean floor and becomes part of the sediment, which can then become rock.

Carbon Cycle Role-Play Card

MARINE SNAIL

Teacher and Student Services, 2008

CALIFORNIA ACADEMY OF SCIENCES

Carbon Cycle Role-Play Card

SEDIMENTS & ROCKS

Group description:

You are the sediments and rocks on our planet. Many rocks and sediments contain carbon from dead animals and plants or from chemical reactions.

Stage position:

On the land.

Options for carbon movement:

1. water
2. atmosphere

Script lines:

I am sediments and rocks and

1. I am giving carbon to water because when I am weathered and eroded, my carbon flows into water.

2. I am giving carbon to the atmosphere in a quick fury because volcanoes erupt and put carbon from rocks back into the atmosphere.

Carbon Cycle Role-Play Card

SEDIMENTS & ROCKS

Teacher and Student Services, 2008

CALIFORNIA ACADEMY OF SCIENCES

Carbon Cycle Role-Play Card

TREES

Group description:

You are the trees on our planet. You have carbon in your structure and use carbon dioxide from the atmosphere to perform photosynthesis.

Stage position:

On the land.

Options for carbon movement:

1. atmosphere
2. sediments and rocks
3. caterpillars

Script lines:

I am a tree and

1. I am giving carbon to the atmosphere when I perform respiration and when I die and decompose.

2. I am giving carbon to sediments and rocks because when I die, I can be buried in sediments and slowly become part of the rocks.

3. I am giving carbon to caterpillars because you have eaten me and will use my carbon for energy or to make your body's structures.

Carbon Cycle Role-Play Card

TREES

Carbon Cycle Role-Play Card

CATERPILLARS

Group description:

You are caterpillars, the larval stage of butterflies. You have carbon in your bodies, which you get from eating carbon-rich food like leaves.

Stage position:

On the land.

Options for carbon movement:

1. atmosphere
2. sediments and rocks

Script lines:

I am a caterpillar and

1. I am giving carbon to the atmosphere because when I respire I release carbon dioxide to the atmosphere.

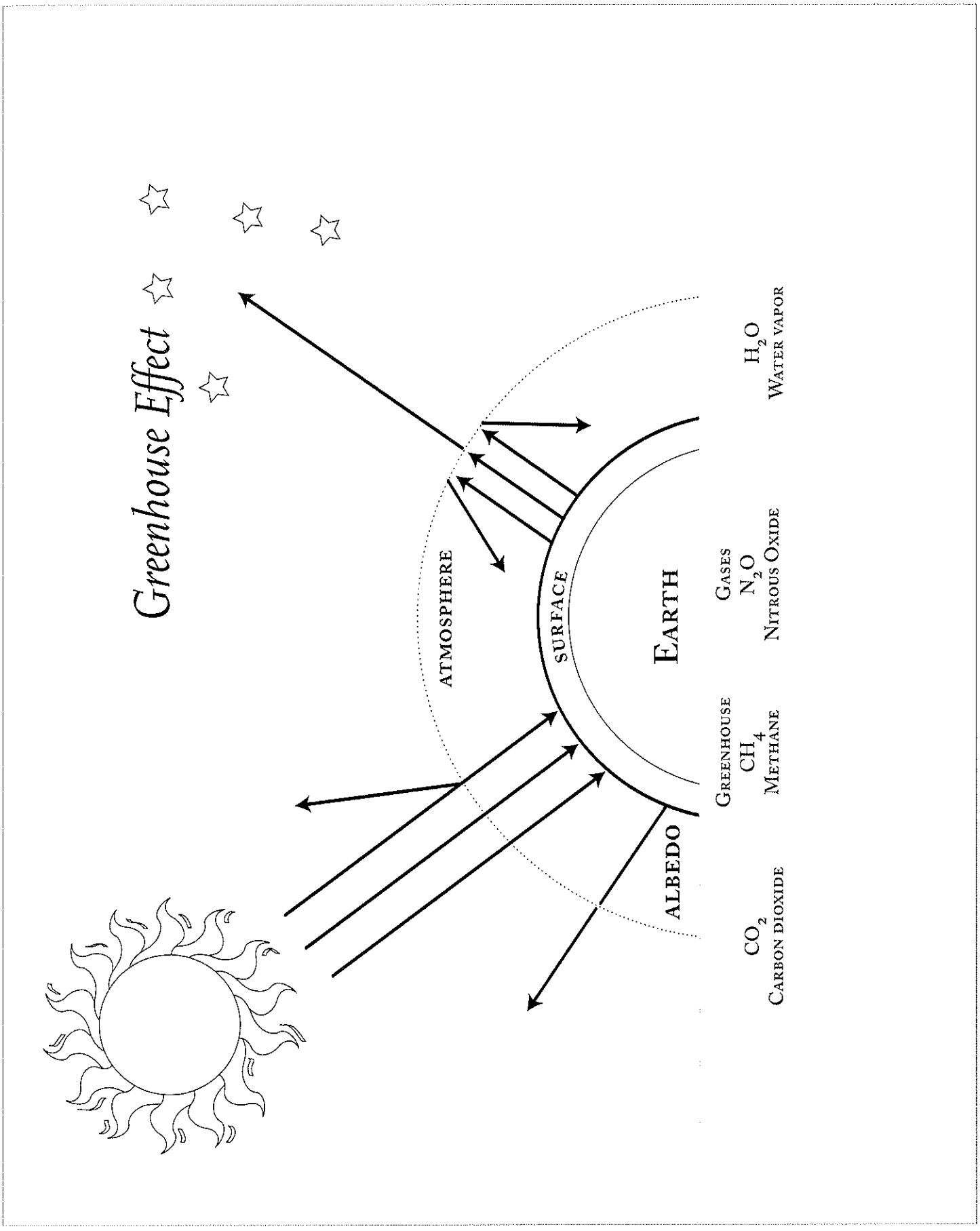
2. I am giving carbon to sediments and rocks because when I die I can be buried and some of the carbon in my body can become part of sediments.

Carbon Cycle Role-Play Card

CATERPILLARS

CALIFORNIA ACADEMY OF SCIENCES

COPY MASTER **Students Directions**: Complete the diagram below by following the directions given by your teacher.



Albedo Effect

materials

For each team

1 sheet of back and white construction paper
2 empty metal food cans, same size
Scotch tape
2 thermometers
Ruler
Desk lamp or sunny window

background

Albedo is a measure of how much light energy is reflected off an object and how much is absorbed and turned into heat energy. A light colored or shiny object will reflect more light than a dull, dark colored object. Albedo plays an important role in heating the earth. Land and water heat up more than snow and ice. The Polar Regions count on a high albedo to keep their region cold. As more of the ice melts in global warming, more heat is absorbed by the ocean and the land mass of Greenland and Antarctica. This causes more melting of the ice sheets and sea ice.

activity time:
30 minutes

directions

1. Use a ruler to measure the height of the cans.
2. Cut the white and black paper to fit the cans' height.
3. Tape the paper to cover the outside of the cans.
4. Check the thermometers for the same reading on both.
5. Put the thermometer in the cans.
6.Place the cans 30 centimeters (12 inches) from the lamp.
7. Turn on the lamp (or use sunny window location) and wait 10 minutes to read the thermometers.

discussion

- What were the temperature readings?
- Why was one cooler than the other? (Light colors reflect more of the light waves than the black paper and the absorption of the light waves increases the temperature.)

vocabulary

Albedo - a measure of how much light energy is reflected off an object and how much is absorbed and turned into heat energy.
Reflect - to send back light, sound or heat to its point of origin (where it came from)

extension

Use tube popsicles and wrap them in white paper or black paper. Put them under a light to see which melts the fastest. Check after 2 minutes and continue checking until there is a noticeable difference.

alignment to national science standards

Unifying Concepts and Processes, Standards A, B, D, E, F, G

alignment to kansas science standards

Science as Inquiry: K-2:1.1.3,1.1.4,1.1.5; 3-4: 1.1.1,1.1.3, 1.1.4; 5-7: 1.1.1,1.1.3,1.1.4, 1.2.2, 1.3.1
Physical Science: K-2: 2.1.1; 3-4: 2.1.1; 5-7: 2.3.1, 2.4.2, 2.4.3
Earth Science: K-2: 4.2.2; 3-4: 4.2.3; 5-7: 4.3.1, 4.4.2
Science and Tech: K-2: 5.1.2
History and Nature of Science: K-2: 7.1.1; 3-4: 7.1.1

Moving on Up:

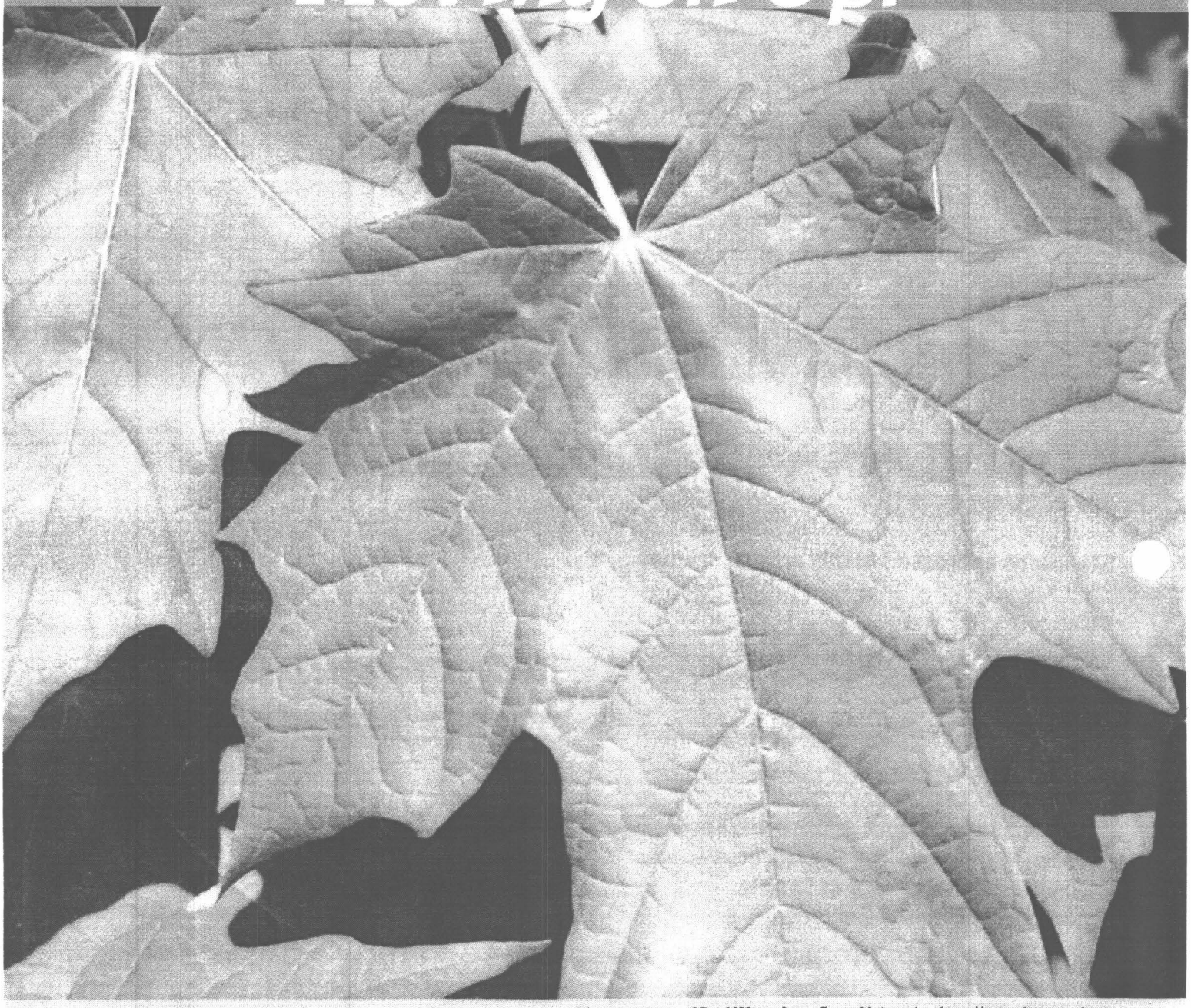
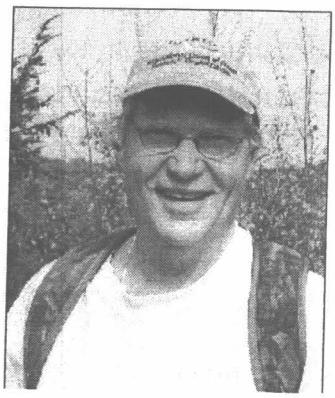


Photo courtesy of Paul Wray, Iowa State University, http://www.bugwood.org.

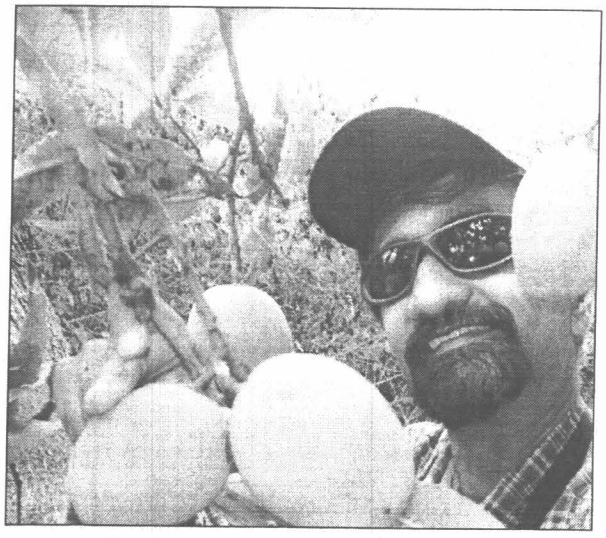
The Possible Impact of Climate Change on Forest Habitat

Meet the Scientists

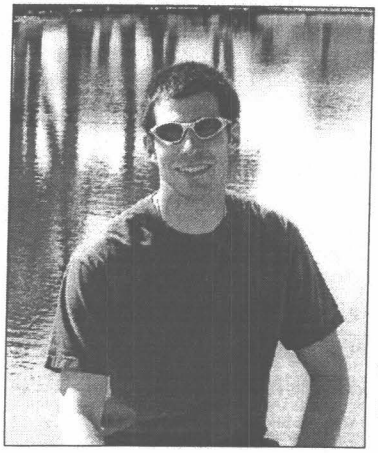
Dr. Louis Iverson, Landscape Ecologist: My favorite science experience is finding out new (to me) patterns, trends, or functions of nature. It really is amazing how organisms interact with other organisms and their environment! One great way to do this is to get out into as many places in nature as possible.



▼ **Mr. Anantha Prasad**, Landscape Ecologist: My favorite science experience is combining what I have learned and gaining insights. For example, I like to look at information about climate change, **topography,** where different plant and animal species are found, and the properties of soils in a particular area. Then, I can tie these different characteristics of the area together to better understand how they relate to each other.



▼ **Mr. Matthew Peters**, Geographic Information Systems (GIS) Analyst (a nə last): A Geographic Information System, or GIS, is a system that collects, stores, manages, and presents information that is linked to a specific place on Earth. As a GIS Analyst, I work with geographic information to help solve problems. My favorite science experience has been collecting vegetation information in the Western United States for a project addressing forest fires. I was on a 6-month internship with the Student Conservation Association (SCA). During that time, I identified plant **species** in wilderness locations to improve our identification of these species using satellite data.

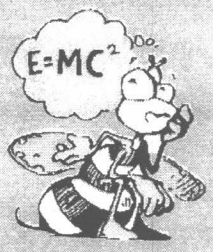


▼ **Dr. Stephen Matthews**, Wildlife Landscape Ecologist: My favorite science experience is coming up with new research questions based either on my current work or a new area of ecology. Then I like to go out and try to solve the problem in an attempt to advance my understanding of the natural world.

When scientists study climate change, they often look toward the future. The job of these scientists is to predict what might happen as the climate changes over time. Because no one knows for sure what will happen in the future, predicting it is a big challenge for scientists. In general, scientists take two main steps to predict what might happen.

First, they look at past or current situations. Often, scientists track what has happened over time, from a time period in the past to the present. This is called a trend. For example, scientists have tracked changes in the **average** yearly temperature since 1880 (**figure 1**).

The second thing scientists do to predict the future is create a computer model. A model is a mathematical representation of a **system**. For example, consider figure 1. If everything continues to be the same in the future as it was in the past, scientists can imagine what the line in figure 1 might look like in the future. They do this by taking the same information collected in the past and applying it to the future. Scientists studying climate change sometimes use different models to represent different possible futures. This is because what happened in the past might be different than what will occur in the future. In the case of rising temperatures, for example, scientists might consider both a future with a small rise in average temperatures, and one with a larger rise in average temperatures.



In this study, the scientists used one model that assumed people will continue to burn **fossil fuels** at an increasing rate for decades into the future. They used another model that assumed people will **conserve** fuels by doing things like driving less and using less electricity. In the second model, the amount of **carbon dioxide emitted** to the atmosphere was expected to be less than the amount emitted in the first model.

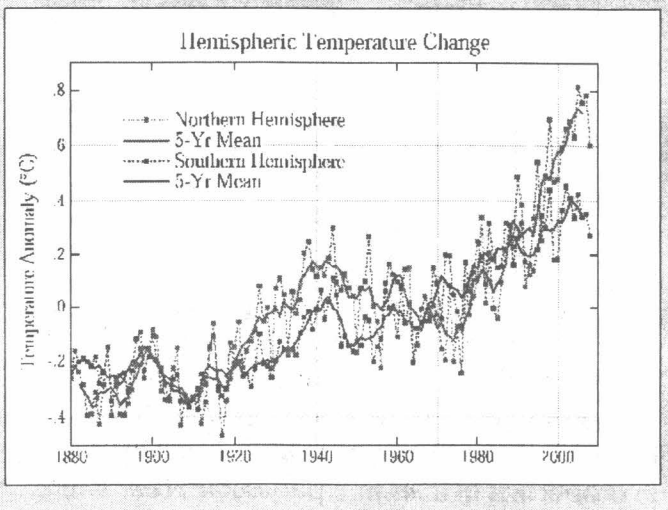
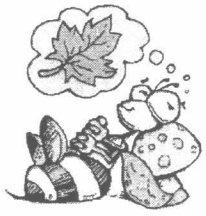


Figure 1. The trend in average yearly temperature since 1880. What trend do you see in this graph? (From http://data.giss.nasa.gov/gistemp/graphs/Fig.A3.pdf)

Thinking About the Environment

Almost everyone lives in a community. Did you know that trees live in communities too? These communities are different than human communities. Forest communities are made up of different species of trees that are commonly found living in the same area. Foresters name these forest communities after the most common species of trees living there.

The scientists in this study were interested both in individual species of trees and in forest communities. To understand how forest communities might change in the future, the scientists had to study individual species of trees. They did this because although trees in the same community live in the same general **habitat**, some trees can survive in other habitats as well. As the climate changes, therefore, some trees in the community might die off, and others might survive. If this happens, the forest community will change.



Introduction

Global climate change is likely to affect plants worldwide. One type of plant that will be affected is trees. Groups of different tree species are found together in forests because the habitat is well suited to those tree species' survival. Some elements of habitat include the amount of yearly rainfall an area receives, the average temperature in each season, the steepness of the land, the area's **elevation**, and the type of soil.

If any of the elements of an area's habitat change, some tree species may not be able to survive. For example, if the average temperature of the area rises, some trees species may not survive long term. If the temperature rises, however, in nearby areas that had previously been too cold for those species in the past, the seeds from those tree species may be transported away from the tree, **germinate**, and begin to grow in the new, warmer areas.

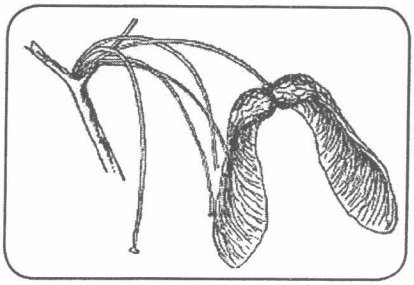
The scientists in this study were interested in trees that live in the Eastern United States (**figure 2**). They wanted to explore how the habitat of these trees might change in the future as the climate changes. They also wanted to know how different tree species might move in response to a changing climate.

Figure 2. The Eastern United States.

How do trees move?

As you know, individual trees cannot move from place to place. Through time and seed **dispersal,** however, the places a tree species lives may change. If the climate in a particular area changes, a tree species may no longer thrive in that original habitat.

The seeds of trees can spread in many ways. Birds and other animals may eat the seeds. Later, they will **defecate** and deposit the seeds in a new area. Seeds can be carried by animals in their fur or even in their mouths and then dropped in another location. Seeds are also blown away by wind or carried by water. If climate change causes the preferred habitat of some tree species to move in one direction or the other, those tree species, over time, will follow the preferred habitat through the movement of their seeds.



What questions were the scientists trying to answer?

Do you think a changing habitat may also affect the animals that live in the Eastern United States? Why or why not?

Methods

The scientists wanted to predict how different tree habitats and forest communities in the Eastern United States might change over time. Scientists believe that the amount of carbon dioxide going into the atmosphere affects Earth's average temperatures. As higher levels of carbon dioxide go into the atmosphere, the average temperature rises. It is important to remember, however, that a certain range of carbon dioxide in the atmosphere is necessary to support life on Earth.

The scientists considered two different possibilities for future levels of carbon dioxide going into the atmosphere. First, they assumed that what happened in the past will continue to happen in the future. The amount of carbon dioxide going into the atmosphere has been rising over time. Therefore, the scientists assumed that the amount of carbon dioxide going into the atmosphere will continue to rise in the future. The scientists used existing information to estimate future average temperatures and future average rainfall in the Eastern United States, if this were the case.

Then, the scientists considered the possibility that people will begin to burn less fossil fuels in the future. This would mean that lower amounts of carbon dioxide would go into the atmosphere. The scientists then used existing information to estimate future average temperatures and future average rainfall in the Eastern United States. This time, however, they assumed that less fossil fuels would be burned than is currently predicted. The scientists considered the preferred habitat of 134 different tree species. Habitat includes things like the amount of rainfall and the average temperature preferred in each season by each species. Then, based on the two possible amounts of carbon dioxide going into the atmosphere, they created maps to show where the center of the preferred habitat of each tree species may be in the future.

Why did the scientists consider what may happen if people burn less fossil fuels in the future?

What is one advantage of using maps to show research results?

Findings

The scientists discovered that, in both possible futures, the preferred habitats of tree species may move in a northerly direction. For the trees already living in the Northeastern United States, some of the preferred habitats may shift into Canada (**figure 3**). For trees living in the far Southeastern United States, their habitat might move across a larger area of the Southern United States (**figure 4**).

Regardless of the habitats studied, the scientists found that the preferred habitats of trees will likely move north if the amount of carbon dioxide going into the atmosphere continues to increase. Even if people burn less fossil fuels in the future, the preferred habitats of eastern tree species may move northward. They will not, however, move as far north from their existing location as compared with the other possibility.

Figure 3. The center of the preferred habitat for sugar maple living in the Northeastern United States will move into Canada.

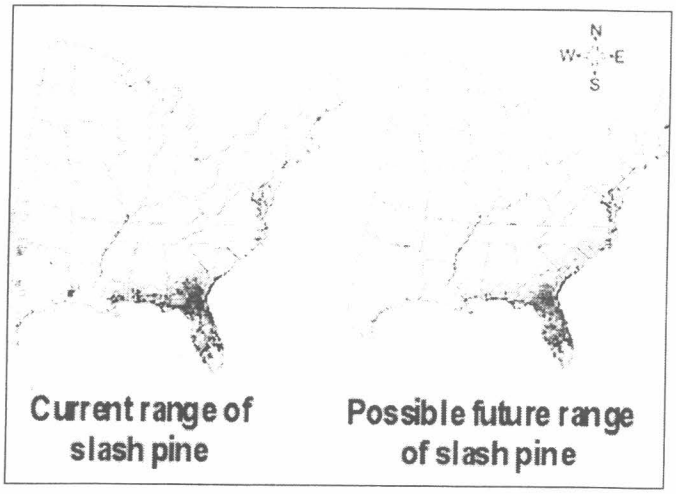


Figure 4. The future preferred habitat for the slash pine tree living in the Southeastern United States will likely move across the south. In which direction is the preferred habitat likely to move? The left map was created from Forestry Inventory and Analysis data, Forest Service. The right map was created using a General Circulation Model (GCM) of climate change.

If the preferred habitat of sugar maple trees moves farther into Canada, what possible impact might this have on U.S. businesses that sell the sweet product of maple trees?

Why will the preferred habitats of most tree species move in a northerly direction?

Discussion

The forest communities of the Eastern United States are likely to change as the climate changes. Not all the possible changes are considered negative. For example, the habitat of some trees may expand. Other tree species, however, may experience a loss in habitat, which would not be a good thing for those tree species. As these changes occur, the forest communities will also begin to change.

Along with changes in forest communities, there may be increasing chances of threats to the trees' health. Examples include danger from invasive animals, plants, and insects. Other possible dangers include diseases, fire, floods, droughts, and changes in how the land is being used by people.

The scientists considered what might happen if people burned less fossil fuels in the future. If people burn even less fossil fuels in the future than the scientists considered, how might the predicted movement of eastern tree species change?

What is one way people might respond to this knowledge of changing forest communities?

Glossary

average (a **v(ə-)**rij): The usual kind or amount. The number obtained by dividing the sum of two or more quantities by the number of quantities added.

carbon dioxide (**kär**-bən **dī** äk sīd): A gas made up of carbon and oxygen with no color or smell.

conserve (kən **sərv**): To avoid wasteful or destructive use of something.

defecate (**de** fi kāt): To have a bowel movement.

dispersal (**di** spər səl): The scattering or spreading in all directions.

elevation (e lə **vā** shən): The height above sea level.

emitted (ē **mit** əd): To throw out or eject.

fossil fuel (**fä** səl fyü(-ə)l): Fuel, such as coal, petroleum, or natural gas, formed from the fossilized remains of plants and animals.

germinate (**jər** mə nāt): To start growing or developing.

habitat (**ha** bə tat): Environment where a plant or animal naturally grows and lives.

invasive (in **vā** siv): Tending to spread.

species (**spē** shēz): Groups of organisms that resemble one another in appearance, behavior, chemical processes, and genetic structure.

system (**sis** təm): An ordered gathering of facts or processes to form a whole.

topography (tə **pä** grə fē): Detailed, precise description of a place or region. Physical features that make up the topography of an area include mountains, valleys, plains, and bodies of water.

Accented syllables are in **bold**. Marks are from the Merriam-Webster Pronunciation Guide.

FACTivity

Time Needed

2 class periods

Materials needed per student group:

- Tree identification books (and/or Internet access) and other resources about trees.
- Two blank maps of the United States.
- Two pieces of blank white 8.5" X 11" paper.
- Markers.

The question you will answer in this FACTivity is: What is the geographic distribution of a particular tree species?

Process for each student group:

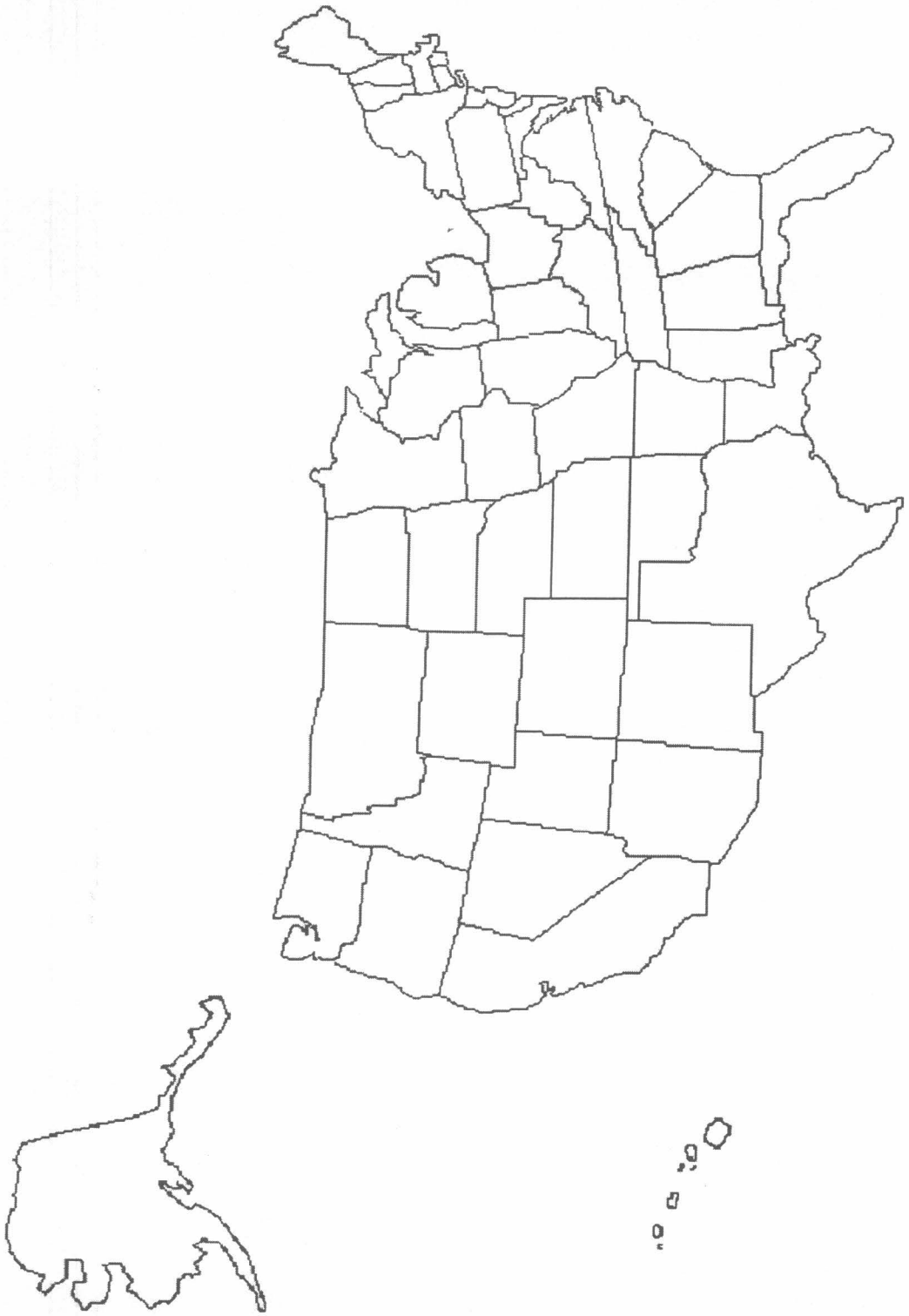
First class period:

Choose a tree species that you would like to study that lives in the United States. Use a tree identification book, the Internet, or the library.

Research information about this tree species. Find the following information about the tree:

Where is the tree species' habitat? When you find out about the areas in which it lives, mark those areas on one of the blank maps provided. Label this map "Current Geographic Distribution of [tree species]."

- What is the climate of the current habitat for the tree species?
- What is the average size of a tree of that species?
- What does the tree look like?
- What is the expected life span of the tree species?
- Do any invasive plants or insects threaten the tree species?



Second class period:

Use this information and any other interesting facts to create a Tree Fact File. The Tree Fact File should be displayed on two 8.5- X 11-inch pieces of paper.

One map should have already been filled out with the current areas where the tree species is found. You will use the other map to make a prediction about where you think the tree species will live as the climate becomes warmer. Think about what you read in the article to help you make this map. Label this map "Predicted Geographic Distribution of Tree Species."

As you make this map, think about your own predictions about how much fossil fuels will be burned in the future.

Once all of the groups have created a Tree Fact File and completed the two maps, the files and maps can be compiled into a class book.

After answering the question posed at the beginning of this FACTivity, consider and discuss this question: "Why is it important to predict the future condition of our natural resources?"

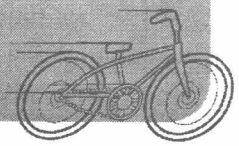
Extensions

If you have already read or will read "There's Snow Place Like Home," compare your maps of the tree species geographic distribution with the wolverine article animal geographic distribution.

- How are the maps similar?
- How are the maps different?
- What conclusions can you draw from comparing these maps?

What You Can Do:

Because keeping carbon emissions down will help the environment, maybe you could ride your bike or walk to school. Make sure it is safe to do so. If you can't walk or ride your bike, take the school bus or have your family carpool with other families in the neighborhood.



If you are a PLT-trained educator, you may use Activity #22: "Trees as Habitats," Activity #77: "Trees in Trouble," and Activity #85: "In the Driver's Seat."

National Science Education Standards

Standards addressed in this article include:

Science as Inquiry:

Understandings About Scientific Inquiry

Life Science:

Regulation and Behavior,
Populations and Ecosystems,
Diversity and Adaptions of Organisms

Science in Personal and Social Perspectives:

Risks and Benefits

Additional Web Resources

U.S. Environmental Protection Agency's Carbon Cycle Movie
http://www.epa.gov/climatechange/kids/carbon_cycle_version2.html

World Almanac for Kids' Carbon Cycle
http://www.worldalmanacforkids.com/WAKI-ViewArticle.aspx?oldpin=xca041350a&-pin=x-ca041350a

The Great Plant Escape- Seed Germination
http://urbanext.illinois.edu/gpe/case3/index.html

Student Conservation Association
http://www.thesca.org

Adapted from Iverson, L.R.; Prasad, A.M.; Matthews, S.N.; and Peters, M. (2007). Estimating potential habitat for 134 eastern U.S. tree species under six climate scenarios. *Forest Ecology and Management*. 254: 390-406.

Appendix 1: Species List
https://www.usanpn.org/nn/species_search

*Available from the USDA PLANTS database (http://plants.usda.gov/java/)

Common Name	Latin Name	Native or Exotic	Lifeform	Lifecycle	Fact Sheet-Plant Guide
alkali sacaton	*Sporobolus airoides*	Native	grass	perennial	Yes
Arizona fescue	*Festuca arizonica*	Native	grass	perennial	Yes
Blue grama	*Bouteloua gracilis*	Native	grass	perennial	Yes
cheatgrass	*Bromus tectorum*	Exotic	grass	annual	Plant Guide only
deergrass	*Muhlenbergia rigens*	Native	grass	perennial	Yes
needle and thread	*Hesperostipa comata*	Native	grass	perennial	Plant Guide only
sideoats grama	*Bouteloua curtipendula*	Native	grass	perennial	Yes
western wheatgrass	*Pascopyrum smithii*	Native	grass	perennial	Yes
butterfly milkweed	*Asclepias tuberosa*	Native	forbs/herbs	perennial	Yes
common dandelion	*Taraxacum officinale*	Exotic	forbs/herbs	perennial	No
common sunflower	*Helianthus annuus*	Native	forbs/herbs	perennial	Plant Guide only
common yarrow	*Achillea millefolium*	Native	forbs/herbs	perennial	Yes
scarlet gilia	*Ipomopsis aggregata*	Native	forbs/herbs	biennial	No
scarlet globemallow	*Sphaeralcea coccinea*	Native	forbs/herbs	biennial	Plant Guide only
yellow sweetclover	*Melilotus officinalis*	Exotic	forbs/herbs	all	Plant Guide only
arroyo willow	*Salix lasiolepis*	Native	shrub/tree	perennial	No
big sagebrush	*Artemisia tridentata*	Native	shrub/tree	perennial	Yes
blue elderberry	*Sambucus nigra ssp. Caerulea*	Native	shrub/tree	perennial	Plant Guide only
boxelder	*Acer negundo*	Native	shrub/tree	perennial	Plant Guide only
curl-leaf mountain mahogany	*Cercocarpus ledifolius*	Native	shrub/tree	perennial	No
Gambel's oak	*Quercus gambelii*	Native	shrub/tree	perennial	No

ponderosa pine	*Pinus ponderosa*	Native	shrub/tree	perennial	Yes
aspen	*Populus tremuloides*	Native	shrub/tree	perennial	Plant Guide only
Pinyon pine	*Pinus edulis*	Native	shrub/tree	perennial	Plant Guide only
redosier dogwood	*Cornus sericea*	Native	shrub/tree	perennial	Plant Guide only
Siberian elm	*Ulmus pumila*	Exotic	shrub/tree	perennial	Yes
rubber rabbitbrush	*Ericameria nauseosa*	Native	shrub/tree	perennial	Yes

Phenology in Your Backyard:
A Guide to Developing Your Own Phenology Garden

Developed by The Arboretum at Flagstaff
As part of a Nina Mason Pulliam Charitable Trust Grant
2015

Phenology in Your Backyard: A Guide to Developing Your Own Phenology Garden

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- **A. The Arboretum at Flagstaff**
- **B. Walking Trail**
- **C. Central Garden**

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Appendix 1: Species Lists

I. What is Phenology?

"Phenology refers to key seasonal changes in plants and animals from year to—such as flowering, emergence of insects and migration of birds—especially their timing and relationship with weather and climate." – The USA National Phenology Network

The word phenology is derived from "phenomenon", meaning an occurrence or circumstance that can be observed. Combined with the suffix "-logy", meaning "to study," we arrive at our currently used term, which first dates back to the late 19th century. Using the power of observation and careful record keeping, scientists have been able to track changes in important biological events, like bird migration and bud burst, in association with changes in weather patterns. When a subject is studied over extended periods of time, and a long-term data set is developed, phenological events associated with a changing climate can be observed and tracked.

This guide focuses on plant-based phenology, but because plants cannot be separated from their animal symbionts, we also suggest observation of pollinators and pests of focal plants. Inclusion of animal associates of your focal plants is also a great way to reinforce the concepts of food chains and food webs.

II. Why Study Phenology?

Someone once said that "timing is everything," and for the study of important phenomena like bud burst and flowering this could not be more true. Perhaps it is easiest to visualize the importance of phenology by taking a closer look at what happens when a plant's timing is earlier or later than usual. A classic example which is frequently witnessed in Flagstaff, AZ, is the premature opening of leaf buds in the spring. Once the leaf bud breaks or bursts, the new leaf tissue is extremely vulnerable to freezing temperatures. A late frost can completely ruin a tree's flush of leaves, requiring the tree to send out a second flush of leaves, which costs the tree valuable resources in terms of energy use. Alternately, if a tree break its leaf buds later than usual, insects that would ordinarily feed on new leaves will go hungry, consequently causing their populations to decrease, which can then affect the ability of birds to feed their hungry young.

What triggers events like bud break and flowering? The answer to this question is not simple, but typically plant phenological traits are triggered by environmental cues, specifically temperatures and moisture levels. Both temperature and precipitation are critical components of climate, thus, as our climate changes, so will the timing of these events.

Over the past century, human activities have released large amounts of carbon dioxide and other greenhouse gases into the atmosphere. Greenhouse gases act like a blanket around Earth, trapping energy in the atmosphere and causing it to warm. This is a natural phenomenon called the "greenhouse effect" and it is necessary to support life on Earth. However, the buildup of too many greenhouse gases ("enhanced greenhouse effect") can change Earth's climate, resulting in negative effects on human health and welfare and

ecosystem function. Right now, the southwestern USA is experiencing one of the highest levels of climate change impacts in North America and has become a nexus for climate change research and study.

The study of phenology can provide important evidence that our climate is changing and reveal trends in how our environment is responding to the changing climate. For example, The U.S. Environmental Protection Agency (EPA, 2014) has identified a set of important indicators that describe trends related to the causes and effects of climate change. Among these are an index of leaf and bloom dates and documented observations in changes in the length of growing season. Anyone who has tried to grow a vegetable garden in northern Arizona knows how important length of growing season can be! Ecological studies, including phenology, often reveal disturbances in food webs.

III. USA National Phenology Network and Project BudBurst

The development of the USA National Phenology Network is credited to the U. S. Geological Survey, but many individuals and organizations have contributed to its continued growth and success, including The University of Arizona. So, what is the USA-NPN?

> "The Network is a consortium of organizations and individuals that collect, share, and use phenology data, models, and related information to enable scientists, resource managers, and the public to adapt in response to changing climates and environments." – U.S.G.S. Fact Sheet, 2011

The Network provides a very informative website (https://www.usanpn.org/node/35) that includes information on phenology indicators, educational and outreach materials, and how to become a participating Citizen Scientist. Through Nature's Notebook (https://www.usanpn.org/natures_notebook), participating members can provide data for a national database where it will be used to make important local, regional, and even global decisions regarding environmental management.

The information and resources provided by the USA-NPN are invaluable and we highly encourage you to explore these sites prior to developing your own phenology garden.

Project BudBurst began in 2007 by folks from the National Ecological Observatory Network and the Chicago Botanic Garden with funding from the National Science Foundation. Project BudBurst aims to "Engage people from all walks of life in ecological research by asking them to share their observations of changes in plants through the seasons." Project BudBurst operates within the broader scope of the USA-NPN, but caters to a slightly different audience. Similarly, you can find extremely helpful information on their website, http://budburst.org/home.

The websites offers species lists, from which you can choose (http://budburst.org/plantstoobserve) and also offers the option of selecting your own species to add to the database. Other features of this program are very similar to the USA-

NPN program in that they offer help with learning how to observe, provide datasheets and a database to which you can submit data, and data visualization tools, but Project BudBurst is primarily focused on plants.

IV. Planning Your Phenology Study: Design Options

The key to a successful garden, of any type, is having a plan! Prior to establishing your garden or trail, it is important to have a few concepts on paper. Begin by deciding **WHO** will be the garden coordinator. This person or group of people will be responsible for making sure that the plan is followed, the garden or trail is maintained, and that data are collected and stored appropriately. It is also a good idea to designate other duties, for example, who will be in charge of watering to establish the garden? Who will be in charge of weeding (if weeds are not the target organism)? And so on.

Next, decide **HOW** you will study phenology. Option A is to plan regular field trips to The Arboretum at Flagstaff to make observations using their established gardens. The pros of this option are that you do not need space for your own garden or resources to develop and maintain a garden, but the cons are that you need to expend resources in getting to and from The Arboretum at Flagstaff. Also, fewer observations will be made, but you might be able to examine more species. Option B is to develop a phenology garden trail. The USA-NPN website provides helpful information https://www.usanpn.org/node/21081 about this option. Typically, a phenology garden trail will fall along a walking path (loops work nicely), and will focus on species already growing there. The pros of this option are that you can likely find a path to use on your school property or nearby and that you will minimize expenses in establishing a new garden. The cons are that you may still need to use time to travel to the path and that you will have less choice in what you observe. Option C is to develop a phenology garden.. This option is the most resource intensive, but in the long run may be easier to maintain and utilize. For option C, the pros are that you will be able to walk outside your classroom and be at your study location. Your students can also take pride in helping with construction and ongoing maintenance of a school garden. The cons are that it will take some resources, including time, to develop and establish your school-based phenology garden.

If you decide to go with option B or C, then you need to decide **WHERE** the garden or trail will be placed. Keep the following things in mind: 1) Locate the site close as you will visit it frequently, 2) choose a uniform, representative habitat to minimize variation due to site location, 3) select a reasonable size to maintain within your available resources. Sites should not be bigger than 15 acres. And 4) make sure you have permission to establish the garden or trail. If you are establishing a garden (Option C), you want to be sure the garden area is near a water source and has good open natural light. Easy access by students and caretakers is also essential.

V. Focal Species Selection and Marking

Once you have developed a garden plan, the next step is to select the focal species for observation and mark these plants so that you know which ones to return to each

observation period. If you choose plants along a nature trail, the number of plants you select should be determined by the amount of time you want to spend making observations. For example, do you want to spend a week-long unit studying them or just a class period? If you have planted a garden, you will need to consider what species will grow well in your selected garden site and soil type. Staff at The Arboretum at Flagstaff can assist you with this process. Appendix 1 lists species taken from the USA-NPN website that can be found/grown in the Flagstaff area. For those who are outside of the Flagstaff area, we suggest looking at the species list on the USA-NPN website to choose your focal species https://www.usanpn.org/nn/species_search.

The key to any successful long-term monitoring project is making sure your plants are labeled clearly and that the labels do not come off! The Arboretum suggests using aluminum hang-tags that can wired onto a plant without hurting the plant. These tags hold up in the field environment very well, but will still need to be replaced periodically. The following website illustrates and provides pricing for the suggested tags, http://www.nationalband.com/nbtwrite.htm.

VI. Monitoring Protocols and Data Presentation

The USA-NPN website provides all of the tools that you will need to begin learning not only how to monitor but what to monitor in terms of different phenophases. We highly suggest joining Nature's Notebook and participating in the training videos found here: https://www.usanpn.org/nn/guidelines/shared-sites. Logging your class' data into Nature's Notebook will provide a sense of importance to the work that has been done, and make an important contribution to a citizen science database. The website can also assist you with visualizing datasets for classroom instruction and interpretation; see the following page, https://www.usanpn.org/nn/connect/visualizations for more information.

VII. References

U.S. Environmental Protection Agency. 2014. Climate change indicators in the United States, 2014. Third edition. EPA 430-R-14-004. www.epa.gov/climatechange/indicators.

U.S. Geological Survey. 2011. The USA National Phenology Network – Taking the Pulse of Our Planet. http://pubs.usgs.gov/fs/2011/3023.