Grade 6: Plants vs. Climate: Who Wins?

Stage 1 – Desired Results

Outcomes and Indicators:

Identify the role of scientific protocols in research by participating in a study of plant phenology within the school's geographic region.

Investigate weather patterns by comparing the results with historical records of the area.

Explore the meteorological implications of climate changes and plant life located within an area by initiating a long-term study of selected plants. [NOTE: This study will be continued by future students matriculating through this class and will also be continuing in grades 7 and 8.]

Share new learning by creating a presentation [media, oral, drama, musical] to present to others.

Understandings: *Students will understand that . . .*	**Essential Questions:** *Students will ask such questions as…*
Weather and climate are two related but different factors in determining which type of plants live within an ecosystem. Phenology is the study of periodic biological events (e.g., flowering) in relation to climatic conditions. Scientific protocols are used to maintain consistency and accuracy in reporting results of an investigation. Long-term scientific research can provide clues as to how plants might respond to a changing climate.	What is the difference between weather and climate? How are they related? How does weather affect plants? How does climate affect plants? What will this effect be over time? What plants are native to my area? Why are they important? Do they break bud/bloom/produce seeds at the same time every year? What is a protocol? Why is it used? How is a protocol made? What can I personally do to help scientists learn about my local climate?
Knowledge: *Students will know . . .*	**Skills:** *Students will be able to . . .*
Earth's atmosphere is comprised of layers. Weather occurs in the troposphere. Weather and climate are not the same. Both vary over time. Climate impacts our quality of life. A changing climate will mean that organisms need to adapt or move if they are to survive. Scientific investigations help researchers learn about the natural world via observations, questioning, and experimentation.	Identify factors 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.

Key Vocabulary

Annual – a plant that flowers, produces seeds, and dies in one growing season

Biennial – a plant that lives for two years and produces flowers and fruits in the second year

Climate – the general pattern of weather in a particular part of the world over a long period of time

Meteorology –the study of earth's atmosphere (a.k.a., "weather")

Native plant – a plant that occurs naturally in a particular region, ecosystem, or habitat without direct or indirect human intervention (generally, plants living here before Europeans arrived). Native plants include all kinds of plants from mosses and ferns to wildflowers, shrubs, and trees. (The US National Arboretum)

Perennial – a plant that lasts for more than two growing seasons, either dying back after each season or growing continuously

Phenology – The study of key seasonal changes in plants and animals from year to year (such as flowering, emergence of insects and migration of birds) – especially their timing and relationship with weather and climate. [National Phenology Network]

Precipitation – water falling from clouds in any form: snow, ice, raindrops, etc.

Protocol – a standard set of procedures to follow when gathering data and communicating information about a scientific inquiry

Qualitative data – any data collected that deals with the description or qualities of a subject (e.g., color, texture, appearance, smell, etc.).

Quantitative data – any data collected that deals with measurable amounts in numbers (e.g., area, time, temperature, humidity, etc.).

Weather – daily atmospheric conditions (e.g., temperature, wind speed, humidity, precipitation, cloud cover, etc.)

Stage 2 – Assessment Evidence

Performance Tasks:	Other Evidence:
Student log/journals/graphs kept up to date with accurate data, organized so the student may readily extract information	On-task with questions
Established protocols used consistently for gathering and recording data and evidence	Demonstrates enthusiasm for learning
Frequent *data collection* indicated within journal/log	Individual motivation and group cooperation
Presentation to others (individual or group) reflects student initiative and academic growth	

Stage 3 – Action Plan

Learning Activities:

Engage Guiding question: "What's above our heads?"

Study layers of the Earth's atmosphere, identify characteristics of each, and create a classroom chart to scale.

Explore Guiding question: "What makes weather different from climate?"

Using a Frayer model and descriptions about weather and climate from a variety of scientific websites, students use a jigsaw format to learn the differences between weather and climate.

Extension: Set up a basic weather station at your school for on-site data collection.

Explain Guiding question: "Is the weather always the same on my birthday?"

Research historic birthday records from the year of birth to the present, to see how weather data may have varied over one's lifetime. The Farmer's Almanac website allows you to view weather reports back to 1945 and you can select the closest zipcode to where students were born. http://farmersalmanac.com/weather-history/.

Questions to consider:

1. What weather conditions have I enjoyed on my birthdays?
2. What causes the weather to be different on the same date, from year to year?

Extension: Explore the RainLog website

Extension: Participate in RainLog data collection

Extension: Invite a guest speaker from the National Weather Service

Elaborate Guiding question: "How do weather and climate affect plant life in this area?"

Citizen Science: Participate in a long-term phenology project of native plants in your region. Begin long-term research project in cooperation with, and under the direction of, The Arboretum at Flagstaff.

Extension: Arrange a field trip to The Arboretum at Flagstaff

Evaluate Guiding question: "What does the future hold for plants and our changing climate?"

Students create products or presentations to demonstrate their new knowledge incorporating material from the previous lessons.

Plants vs. Climate: Who Wins?

Grade 6: 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 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information **Crosscutting Concepts** 5. Energy and matter: Flows, cycles, and conservation 7. Stability and change **Disciplinary Core Ideas** **Life Sciences** LS2: Ecosystems: Interactions, energy, and dynamics LS4: Biological evolution: Unity and diversity [adaptation] **Earth and Space Science** ESS2.D: Weather and Climate ESS3.C: Human Impacts on Earth Systems ESS3.D: Global Climate Change	**Science** **Inquiry** S1C1PO3 Locate research information, not limited to a single source, for use in the design of a controlled investigation. 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. S1C3PO3 Evaluate the observations and data reported by others. S1C3PO4 Interpret simple tables and graphs produced by others. S1C3PO6 Formulate new questions based on the results of a completed investigation. S1C4PO2 Display data collected from a controlled investigation. S1C4PO3 Communicate the results of an investigation with appropriate use of qualitative and quantitative information. S1C4PO5 Communicate the results and conclusion of the investigation. **History and Nature of Science** S2C2PO3 Apply the following scientific processes to other problem solving or decision making situations: • Observing • Questioning • Communicating • Organizing data • Inferring • Identifying variables • Predicting **NOTE**: Classifying and generating hypothesis are a part of this PO but are not addressed in this lesson.	1. The sun is the primary source of energy for Earth's 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 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.

	Life Science S4C1PO1 Explain the importance of water to organisms. S4C3PO1 Explain that sunlight is the major source of energy for most ecosystems. S4C3PO2 Describe how the following environmental conditions affect the quality of life: • climate **NOTE**: Water quality, population density, and smog are a part of this PO but are not addressed in this lesson. **Earth and Space Science** S6C2PO1 Describe the properties and the composition of the layers of the atmosphere. S6C2PO5 Analyze the impact of large-scale weather systems on the local weather. **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)** **Math: Ratios and Proportional Relationships (RP)** **Understand ratio concepts and use ratio reasoning to solve problems.** 6.RP.A.1. Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. [chart depicting the atmospheric layers] *Math: Statistics and Probability (SP***)**	

	Develop understanding of statistical variability. 6.SP.A.1. Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers. [In lesson: variability in weather on the date of one's birth] 6.SP.A.2. Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape. 6.SP.A.3. Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number. **Summarize and describe distributions.** 6.SP.B.5. Summarize numerical data sets in relation to their context, such as by: a. Reporting the number of observations. b. Describing the nature of the attribute under investigation, including how it was measured and its units of measurement c. Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered. d. Relating the choice of measures of center and variability to the shape of the data distribution and the context in which the data were gathered. **Standards for Mathematical Practice (MP)** 6.MP.2. Reason abstractly and quantitatively. 6.MP.3. Construct viable arguments and critique the reasoning of others. 6.MP.5. Use appropriate tools strategically.	

Plants vs. Climate: Who Wins?

Materials Required – Grade 6

Websites:

- http://www.windows2universe.org/earth/Atmosphere/layers.html ("Windows to the Universe", National Earth Science Teachers Association)
- http://www.youtube.com/watch?v=e0vj-0imOLw&feature=youtu.behttp://www.youtube.com/watch?v=e0vj-0imOLw&feature=youtu.be (differences between weather and climate)
- http://www.srh.noaa.gov/jetstream/synoptic/wxmaps.htm#draw (surface weather maps)
- http://www.ncdc.noaa.gov/oa/climate/normals/usnormals.html (NOAA - weather "averages")
- www.rainlog.org (Citizen Science project for RainLog – precipitation records for AZ)
- https://www.usanpn.org/nn/species_search (National Phenology Network)
- http://www.sega.nau.edu (Southwest Experimental Garden Array at Northern Arizona University)
- http://mprlsrvr1.bio.nau.edu:8080/?command=RTMC&screen=Arboretum%20at%20Flagstaff (SEGA weather data)

Books/media:

- How We Know What We Know about Our Changing Climate, Lynne Cherry and Gary Braasch, p. 10-11
- ScienceSaurus: A Student Handbook, Grade 6-8 by GREAT SOURCE, p. 212-230 (optional)

Photocopies:

- Frayer model – weather and climate (1 copy of each page/student)
- "Chain Reaction: Weather" (page 6) 1 copy/every 2-4 students)

For the following, *divide the class into six groups. The number of copies needed will be determined by the number of students. If you have 30 students, make 5 copies of each handout.* [See the "Weather-Climate" folder])

- Climate Impacts Group
- Diffen
- NSIDC (National Snow and Ice Data Center)
- NASA (National Atmospheric and Space Administration)
- UCAR (University Corporation for Atmospheric Research)
- NOAA (National Oceanic and Atmospheric Administration)

Art supplies:

- Butcher paper and art supplies (for atmospheric chart and for final presentation)

Science equipment:

- Weather station items (optional): thermometer, hygrometer, Beaufort scale

Miscellaneous:

- Journals for students [**or** add to science notebooks if already being used]
- Document camera, computer and media projector (if available)
- Adhesive tape and glue, markers/crayons

Rubric: Final Product or Presentation – Grade 6

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 theme of the product or presentation. No obvious errors are evident.	Most content is scientifically accurate, used in proper context, and supports the overall theme of the product or presentation. 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 product or presentation and are used accurately. Students demonstrate a thorough understanding of each word.	4 key vocabulary words from the lesson are incorporated into the product or presentation 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 product or presentation 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 product or presentation but may be used inaccurately. Students demonstrate little understanding of each word.
Audience Appeal	Product/presentation is highly engaging to the audience: visually appealing, creative, and includes audience interaction when feasible.	Product/presentation is engaging to the audience: visually appealing, creative, and may include audience interaction when feasible.	Product/presentation does little to engage the audience. May lack visual appeal, creativity, and/or indicates a lack of preparation.	Product/presentation 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, developing, and delivering the product or presentation.	Most members of the group participate equally in designing, developing, and delivering the product or presentation.	Few members of the group participate equally in designing, developing, and delivering the product or presentation.	One member of the group carries the assignment by designing, developing, and delivering the product or presentation without benefit of other group members.

What is WEATHER?

Definition (in your own words) Weather is …	**Facts/Characteristics**
Important To Know	**Challenges of studying weather**

Essential Questions

- How accurate was my original definition?
- What did I learn about weather?
- How important is weather to plants? To Flagstaff?
- What challenges are there in studying weather?

What is CLIMATE?

Definition (in your own words) Climate is …	**Facts/Characteristics**
Important To Know	**Challenges of studying climate**

Essential Questions

- How accurate was my original definition?
- What did I learn about climate?
- How important is climate to plants? To Flagstaff?
- What challenges are there in studying climate?

Grade 6: Plants vs. Climate: Who Wins?

Subject & Topics

Science, ACCR: layers of the atmosphere, weather and climate, phenology, scientific investigations, protocols

Arizona Academic Standards for Science 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 6 correlaties 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
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Crosscutting Concepts

5. Energy and matter: Flows, cycles, and conservation
7. Stability and change

Disciplinary Core Ideas

Life Sciences

LS2: Ecosystems: Interactions, energy, and dynamics

LS4: Biological evolution: Unity and diversity [adaptation]

Earth and Space Science

ESS2.D: Weather and Climate

ESS3.C: Human Impacts on Earth Systems

ESS3.D: Global Climate Change

Objectives

1. Create a classroom chart of layers of the atmosphere and what happens within each, focusing special attention on the troposhere and the stratosphere.
2. Complete Frayer models of weather and climate and discuss, reflect, and clarify knowledge of both.
3. Research historic meteorological data for one's birthday, from year of birth to the present.
4. Begin a study of phenology of native plants on school grounds and/or at The Arboretum at Flagstaff and follow established scientific protocols while gathering data and recording observations. (**NOTE**: this project will initiate a long-term phenological research project in conjunction with The Arboretum at Flagstaff.)
5. Create presentations (oral, media, drama) to demonstrate new learning to the class or other audience.

Evidence of Mastery

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

Presentation to others (individual or group) reflecting student initiative and academic growth

Active *participation* in small-group assignments

Key vocabulary

Annual – a plant that flowers, produces seeds, and dies in one growing season

Biennial – a plant that lives for two years and produces flowers and fruits in the second year

Climate – the general pattern of weather in a particular part of the world over a long period of time.

Meteorology –the study of earth's atmosphere (a.k.a., "weather").

Native plant – a plant that occurs naturally in a particular region, ecosystem, or habitat without direct or indirect human intervention (generally, plants living here before Europeans arrived).

Perennial – a plant that lasts for more than two growing seasons, either dying back after each season or growing continuously

Phenology – The study of key seasonal changes in plants and animals from year to year (such as flowering, emergence of insects and migration of birds) – especially their timing and relationship with weather and climate. [National Phenology Network]

Precipitation – water falling from clouds in any form: snow, ice, raindrops, etc.

Protocol – a standard set of procedures to follow when gathering data and communicating information about a scientific inquiry.

Qualitative data – any data collected that deals with the description or qualities of a subject (e.g., color, texture, appearance, smell, etc.).

Quantitative data – any data collected that deals with measurable amounts in numbers (e.g., area, time, temperature, humidity, etc.).

Weather – daily atmospheric conditions (e.g., temperature, wind speed, humidity, precipitation, cloud cover, etc.)

Materials

Websites:

- http://www.windows2universe.org/earth/Atmosphere/layers.html ("Windows to the Universe", National Earth Science Teachers Association)
- http://www.youtube.com/watch?v=e0vj-0imOLw&feature=youtu.behttp://www.youtube.com/watch?v=e0vj-0imOLw&feature=youtu.be (differences between weather and climate)
- http://www.srh.noaa.gov/jetstream/synoptic/wxmaps.htm#draw (surface weather maps)
- http://www.ncdc.noaa.gov/oa/climate/normals/usnormals.html (NOAA - weather)
- www.rainlog.org (Citizen Science project for RainLog – precipitation records for AZ)
- https://www.usanpn.org/nn/species_search (National Phenology Network)
- http://www.sega.nau.edu
- http://mprlsrvr1.bio.nau.edu:8080/?command=RTMC&screen=Arboretum%20at%20Flagstaff (SEGA weather data)

Books/media:

- How We Know What We Know about Our Changing Climate, Lynne Cherry and Gary Braasch, p. 10-11
- ScienceSaurus: A Student Handbook, Grade 6-8 by GREAT SOURCE, p. 212-230 (optional)

Photocopies:

- Frayer model – weather and climate (1 copy of each page/student)
- *Phenology in Your Backyard* Guide
- "Chain Reaction: Weather" (page 6) 1 copy/every 2-4 students)

For the following, *divide the class into six groups. The number of students will determine*

	the number of copies needed. If you have 30 students, make 5 copies of each handout. • Climate Impacts Group • Diffen NSIDC (National Snow and Ice Data Center) • NASA (National Atmospheric and Space Administration) • UCAR (University Corporation for Atmospheric Research) • NOAA (National Oceanic and Atmospheric Administration) • NSIDC (National Snow and Ice Data Center) **Art supplies:** • Butcher paper and art supplies (for atmospheric chart and for final presentation) **Science equipment:** • Weather station items (optional): min/max thermometer, anemometer, barometer **Miscellaneous**: • Journals for students [**or** add to science notebooks if already being used] • Document camera (if available) • Computer and media projector (if available) • Adhesive tape and glue

Engage

Guiding question*:* "What's above our heads?"

Prepare:

1. Use a document camera to present page 6 of the Chain Reaction "Weather" issue **OR** provide 1 copy of this page for small groups of students (2-4 per group).
2. Gather art supplies: butcher paper and markers for the atmospheric chart.
3. Review the "Windows to the Universe" and the weather-climate differences websites: http://www.windows2universe.org/earth/Atmosphere/layers.html and http://www.youtube.com/watch?v=e0vj-0imOLw&feature=youtu.behttp://www.youtube.com/watch?v=e0vj-0imOLw&feature=youtu.be

NOTE: *ScienceSaurus* 6-8 (p. 212-230) is also an excellent reference, but students may need to be introduced to the metric system if this resource is used.

Present:

Ask students the guiding question: "What's above our heads?" Allow them to share their responses, making note of all ideas presented.

Using page 6 (Chain Reaction) and the Windows to the Universe website, ask students to identify the layers of the atmosphere, paying particular attention to the troposphere and the stratosphere. Ask:

1. Why do you think that one source cites four layers of the atmosphere while another cites five? [*Scientific observations are based upon clear evidence and are made by humans. They may not always agree on how that evidence and information should be presented*.]
2. Is this significant? Why or why not? [*In this case, it is generally accepted that there are five layers of atmosphere, but not all scientists agree. It is important to know that there are different ways of looking at the world*.]
3. Why might scientists sometimes disagree on such issues? [*Some prefer to separate evidence as much as possible, while others prefer to "lump" it together. Scientists themselves refer to the "lumpers" and the "splitters" – especially when it comes to classifying species*.]
4. Does that make one scientist's data less important than another's? [*No*. *It really depends on the question that is being asked by the investigator*.]

Student activity:

In their journals, students note key characteristics of each layer. Pay special attention to:

- Troposphere (weather happens here, the role of the sun to Earth and the hydrologic cycle)
- Stratosphere (the role of ozone)

By class consensus, students select criteria for each layer and create a classroom chart of these layers. (*The chart should be drawn to scale as much as possible*! Assign small groups to various parts of this chart: one group will determine the amount of space to devote to each layer, while other groups are assigned a specific layer.) Post chart for the duration of this lesson.

Explore

Guiding question: "What makes weather different from climate?"

Prepare:

1. Copy Frayer model worksheets for students.
2. Divide class into six working groups.

Present:

Distribute a copy of the Frayer models to each student. Students write "WEATHER" or "CLIMATE" in the appropriate ovals. (These will be cut out when completed and glued into the student's journal.)

Ask: What is *weather?* What is *climate?* As a class, discuss the respective models and ask students to complete what they *think* they know.

Student activity:

Divide the class into six groups and distribute copies of the six different "Weather-Climate" documents to each group, making sure that all students in the same group have the same sheet but **only** that sheet. (You may need to explain that "meteorology" is the scientific word for the study of weather.) Allow approximately 10-15 minutes for each group to read and discuss its information, and prepare to share key aspects of that information with others. Encourage students to use their Frayer models to make notes as each of them will be sharing their group's information with others.

Number off every student in each sub-group (numbers 1-6) and ask the class to rearrange themselves so that those with #1 are together, those with #2 are together, etc. In their new groups, students will share what they learned about the differences between weather and climate. Plan to spend 15 minutes for this segment. You may find it helpful to allocate 10 minutes for the sharing of information from each group, followed by 5 minutes of discussion within that group. [Any discrepancies will be resolved via a class discussion later.]

When all groups have finished, revisit the Frayer models they initiated earlier.

Ask:

1. What is weather? What is climate?
2. What is the advantage of using more than one scientifically valid resource when studying an issue?

Students should make any corrections to their Frayer models at this time and glue their final pages into their journals. (Remind them that it is okay not to have a "perfect" paper in their journals: there will likely be some crossing out and erasing – and that is what science is all about! We learn as we go, refining our focus and revising our work as we uncover more information.)

As a class, watch the brief (1:04 minutes) video depicting the difference between weather and climate. http://www.youtube.com/watch?v=e0vj-0imOLw&feature=youtube

Extension: Set up a basic weather station on your school campus and have students record daily temperatures (min/max thermometers are helpful for this), wind speed*, relative humidity, cloud cover. Compare their data with that of an established weather station. The Arboretum at Flagstaff has been an official NOAA weather station for over 30 years. Our station number is 023009, and our name is Flagstaff 4 SW,AZ US. You can search by station number or zip code. The website for the NOAA data is: http://www.ncdc.noaa.gov/cdo-web/. In 2015, the Southwest Experimental Garden Array (SEGA) will launch a state-of-the-art weather station at The Arboretum and nine other locations across northern Arizona. Data can be accessed here: http://mprlsrvr1.bio.nau.edu:8080/?command=RTMC&screen=Arboretum%20at%20Flagstaff.

*Wind speed may be measured with an anemometer. If funding is not avialable, consider using the Beaufort Scale to enhance critical observations of the immediate environment. Visit http://www.spc.noaa.gov/faq/tornado/beaufort.html for a chart that is readily useable with students. Demonstrate how to convert "knots" to "miles per hour" at http://www.disastercenter.com/convert.htm which also includes the Beaufort Scale .

Explain

Guiding question: "Is the weather always the same on my birthday?"

Prepare:

- Computer with a media projector (or Smart Board) is preferable for this activity. (If unavailable, bring in sample weather forecasts from the daily newspaper – preferably ones that indicate isobars and/or other meteorological conditions.)

Present:

Ask the following questions to launch a class discussion:

1. What weather conditions have we each enjoyed on our birthdays?
2. What affects local weather? [See *ScienceSaurus: A student handbook*]

Use student responses to help them understand that weather is what's "happening above our heads", is variable from year to year, and is dependent upon many variables. Refer to the classroom atmospheric layers chart to identify where weather happens.

Display http://www.srh.noaa.gov/jetstream/synoptic/wxmaps.htm#draw to have students become aware of how meteorologists use surface weather maps to "plot" the weather for a specific place and time.

Student activity:

Students will research historic records for their birth year to see what weather data they can find for that date in history. (They should look for meteorological records in their school area, whether or not this is where they were born). What other weather records can they find for their birth date? Encourage them to record the weather information for every year in a table, chart, or graph format. Share their information with the class by making a classroom graph of means, highlighting any major differences in their research. (**Note**: This is an excellent opportunity to incorporate the math standards for such concepts as range, mean, median. Include a variety of methods to represent their data. Refer to Math standards for guidance OR work with your math teacher to assist in reinforcing this learning.)

You can suggest the following website to students to help them find this information: http://farmersalmanac.com/weather/ (you can enter dates back to 1945 and search by location)

Questions to review/consider:

- What weather conditions have occurred on my birthdays?
- What causes the weather to be different in the same place, on the same date, from year to year? (Focus on the information gleaned during the Explore lesson.)
- Considering all the data collected by the class, do there appear to be any trends with the local weather? (CAUTION! It is important for students to understand that *geologic time* is vastly different from the time they mark with each passing day. Their collective data represent one very brief snapshot in time and should not be considered to be an indicator of whether or not climate change is occurring in your area. Nonetheless, this is a tool that scientists use to consider climate over geologic time.)

Fun fact: Do you know how the "average" daily temperature is computed? [NOAA updates this information every 30 years. This was last done at the end of 2010. See http://www.ncdc.noaa.gov/oa/climate/normals/usnormals.html for details.] When we see a TV weather person state the "average" temperature for today, they are referring to a 30-year window of time…far longer than any 6^{th} grade student has been on the planet!

Extension*:* Visit the website for the RainLog project at www.rainlog.org and see where the nearest RainLogger might be. Explore that site to learn what precipitation is being recorded in AZ for the past few years and compare data from Flagstaff with that of other sites around the state.

Extension: Become a RainLogger! The RainLog site explains how to become a rain logger, describes the type of rain gauge needed, reviews protocols, and shows how you record your data. It also produces a summary of the weather patterns that have been monitored throughout the state for the previous month, as well as any long-term predictions (e.g., the development of El Niňo or La Niňa).

Extension: Invite a guest speaker from the National Weather Service (NWS) to come and give a presentation. Many NWS staff members are available year-round to provide this service.

Elaborate

Guiding question: "How do weather and climate affect plant life in this area?"

Initiate a research project [plant phenology in your area].

Prepare:

- Review the National Phenology Network (NPN) website: https://www.usanpn.org/nn/species_search
- Review "Phenology in Your Backyard", a guide to developing your own phenology garden, developed by The Arboretum at Flagstaff. This guide will include plant species lists for Flagstaff, AZ. Contact the Director of Research at The Arboretum for assistance with plant identification in your school environment.

Present:

Read *Inspired by Students 100 years ago, Today's Students Record the Seasons* (How We Know… pages 10-11) using a document camera. (If a camera is not available, read the information to the class.)

Initiate a class discussion on how they can participate as Citizen Scientists.

- What are some of the plants we might observe? (Use the list from The Arboretum at Flagstaff, extracted from the National Phenology Project.)
- What are some special adaptations of the plant(s) we will be researching? How do those help that plant survive in the local environment? How does the availability of water impact where a plant lives? How does the climate of our area impact what lives here?
- When scientists engage in research, what "rules" do they need to follow to ensure their data/evidence is correct? (Introduce the term "scientific protocol" and see if students can identify ways that their data will be accurate, consistent, able to be corroborated, and publishable.)

Student activity:

Launch your investigation! Participate in citizen science using established protocols for collecting and recording data. [*Reminder to teachers: this is intended to be a long-term project that will eventually help scientists discern long-term trends in weather patterns for your area. Students should not be encouraged to draw conclusions based upon observations created during one academic year. Nonetheless, they should remember that the observations made by Canadian students 100 years ago has provided evidence from which scientists today can make valid comparisons. Their work will be important!*]

The Arboretum staff will assist with helping you establish your research project, including working with protocols to use with your students, identifying the various stages of a plant's phenology (in addition to what is available on the National Phenology Network website), and how/where/when to post data.

Extension: Arrange a field trip to The Arboretum at Flagstaff to see the SEGA weather station, a phenology garden, and the I-STEM Learning Center.

Evaluate

Guiding question: "What might the future hold for plants and our changing climate?"

Prepare:

- Assemble any supplies students may need for creating visuals (if desired) for a final presentation.

Present:

(You may ask each individual student to create a final presentation OR may have them continue to work in their small groups.) Provide guidance as 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. The following questions may be helpful:

1. How do weather and climate impact the capacity of an organism to survive long-term?
2. What local plant adaptations help them survive in this area? What predictions might we make about their future if the area becomes warmer and drier?
3. How can I help contribute to scientific research? What will help ensure that my work is valid and reliable?
4. How might scientists 100 years from now use our research?

Student activity:

Students create presentations to demonstrate their new learning. Use the rubric to assess students' products.

Closure:

Revisit the question: "Plants vs. Climate: Who Wins?" Each small group of students creates a 12-18 word bumper sticker that summarizes their group's response. Post on classroom walls.

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 S1C1PO3 S1C2PO5 S1C4PO3 and PO5 S2C2PO3 S4C3PO2 S6C2PO1	**ENGAGE – ACCR** 6-8.RST.1 6-8.RST.4 6-8.RST.7	**ENGAGE – Math** 6.RP.A.1	**ENGAGE – Technology** S1C1PO1
EXPLORE – Science S1C2PO5	**EXPLORE – ACCR** 6-8.RST.1 6-8.RST.4	**EXPLORE – Math** None	**EXPLORE – Technology** S1C1PO1 S2C2PO1
EXPLAIN – Science S1C1PO3 S1C3PO3, PO4, PO6 S1C4PO3 and PO5 S6C2PO5 (if using regional or national weather maps)	**EXPLAIN – ACCR** 6-8.RST.1 6-8.RST.4 6-8.RST.7	**EXPLAIN – Math** 6.SP.A.1 6.SP.A.2 6.SP.A.3 (aggregation of class data) 6.SP.B.5	**EXPLAIN – Technology** S1C3PO1
ELABORATE – Science S1C1PO3 S1C2PO4 and PO5 S1C3PO3, PO4, and PO6 S1C4PO2, PO3, and PO5 S2C2PO3	**ELABORATE – ACCR** 6-8.RST.3, RST.4, and RST.7	**ELABORATE – Math** 6.RP.A.1 6.SP.B.5 6.MP.2, 3, and 5	**ELABORATE – Tech.** S1C1PO1 S1C3PO1 S1C4PO2 S2C2PO1 S5C2PO1

S4C1PO1 S4C3PO2			S5C3PO1 S6C1PO3
EVALUATE – Science S1C4PO5	**EVALUATE – ACCR** None	**EVALUATE – Math** None	**EVALUATE – Tech.** S1C4PO2 S2C2PO1 S5C2PO1 S6C1PO3

Standards

Science: Strand 1 - Inquiry

C1 **Observations, Questions, and Hypotheses:** Formulate predictions, questions, or hypotheses based on observations. Locate appropriate resources.

PO 3. Locate research information, not limited to a single source, for use in the design of a controlled investigation.

C2 **Scientific Testing (Investigating and Modeling):** Design and conduct controlled investigations.

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

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

C3 **Analysis and Conclusions:** Analyze and interpret data to explain correlations and results; formulate new questions.

PO 1. Analyze data obtained in a scientific investigation to identify trends.

PO 3. Evaluate the observations and data reported by others.

PO 4. Interpret simple tables and graphs produced by others.

PO 6. Formulate new questions based on the results of a completed investigation.

C4 **Communication**: Communicate results of investigations.

PO 2. Display data collected from a controlled investigation.

PO 3. Communicate the results of an investigation with appropriate use of qualitative and quantitative information.

PO 5. Communicate the results and conclusion of the investigation.

Science: Strand 2 - History and Nature of Science

C2 **Nature of Scientific Knowledge**: Understand how science is a process for generating knowledge.

PO3. Apply the following scientific processes to other problem solving or decision making situations:

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

NOTE: Classifying and generating hypothesis are a part of this PO but are not addressed in this lesson.

Science: Strand 4 - Life Science

C1 **Structure and Function in Living Systems:** Understand the relationships between structures and functions of organisms.

PO 1. Explain the importance of water to organisms.

C3 **Populations of Organisms in an Ecosystem:** Analyze the relationships among various organisms and their environment.

PO 2. Describe how the following environmental conditions affect the quality of life:

- climate

NOTE: Water quality, population density, and smog are a part of this PO but are not addressed in this lesson.

Science: Strand 6 - Earth and Space Science

C2 **Earth's Processes and Systems:** Understand the processes acting on the Earth and their interaction with the Earth systems.

PO 1. Describe the properties and the composition of the layers of the atmosphere.

PO 5. Analyze the impact of large-scale weather systems on the local weather.

AZ College and Career Readiness Standards

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)**

Math: Ratios and Proportional Relationships (RP)

Understand ratio concepts and use ratio reasoning to solve problems.

6.RP.A.1. Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. [chart depicting the atmospheric layers]

Math: Statistics and Probability (SP)

Develop understanding of statistical variability.

6.SP.A.1. Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers. [In lesson: variability in weather on the date of one's birth]

6.SP.A.2. Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape.

6.SP.A.3. Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number.

Summarize and describe distributions.

6.SP.B.5. Summarize numerical data sets in relation to their context, such as by:

a. Reporting the number of observations.
b. Describing the nature of the attribute under investigation, including how it was measured and its units of measurement
c. Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.
d. Relating the choice of measures of center and variability to the shape of the data distribution and the context in which the data were gathered.

Standards for Mathematical Practice (MP)

6.MP.2. Reason abstractly and quantitatively.

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

6.MP.5. Use appropriate tools strategically.

Technology

Creativity and Innovation

S1C1PO1 Analyze information to generate new ideas and products.

S1C3PO1 Identify patterns and trends to draw conclusions and forecast possibilities.

S1C4PO2 Use digital collaborative tools to analyze information to produce original works and express ideas.

Communication and Collaboration

S2C2PO1 Communicate and collaborate for the purpose of producing original works or solving problems.

Digital Citizenship

S5C2PO1 Promote digital citizenship by consistently leading by example and advocating social and civic responsibility to others.
S5C3PO1 Research a current technology and describe its potential use to solve an economic, environmental, health, political, scientific, or social problem.

Technology Operations and Concepts

S6C1PO3 Choose technology applications appropriate for the audience and task.

ChainReAction • 6

Keep a watch on: WEATHER

Starting a storm

Weigh the sky

Hot or not?

Freaky weather

Stories of Science and Learning from Arizona State University

ASU

BUBBLE, BUBBLE, TOIL AND TROUBLE (THAT'S SHAKESPEARE). EVERYWHERE AROUND US THE ATMOSPHERE IS STIRRING, BUBBLING, CHURNING AND FROTHING. WE CALL ALL THAT THRASHING...

WEATHER

ChainReaction

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Chain Reaction:
A series of chemical reactions in which the products of each reaction activate additional molecules of the reactants, thus causing new reactions...

http://chainreaction.asu.edu

Hot enough for you? How about that blizzard last week? We sure could use some rain. Do you think we will ever see the sun again? We've all heard those phrases or similar snippets of conversation. People love to discuss the weather. Talking about the weather is natural. Of course it is! The weather plays a role in how we respond to our environment, and how we live each and every day. Simply defined, weather describes conditions in the atmosphere over short periods of time, usually in terms of hours or days. The term "climate" refers to something much bigger. Climate is defined as the average of weather conditions over a longer period of time—months, years, or thousands of years. Weather and climate shape the world in which we live. Both will help define the future. Want to learn more? Turn the page and start your own personal chain reaction of learning.

Conrad J. Storad, Editor

Contents

PHOTO: Summer monsoon lightning cracks over the Grand Canyon, seen from Point Sublime on the north rim. Michael Nichols photo.

A recipe for STORMS

3 . condensation

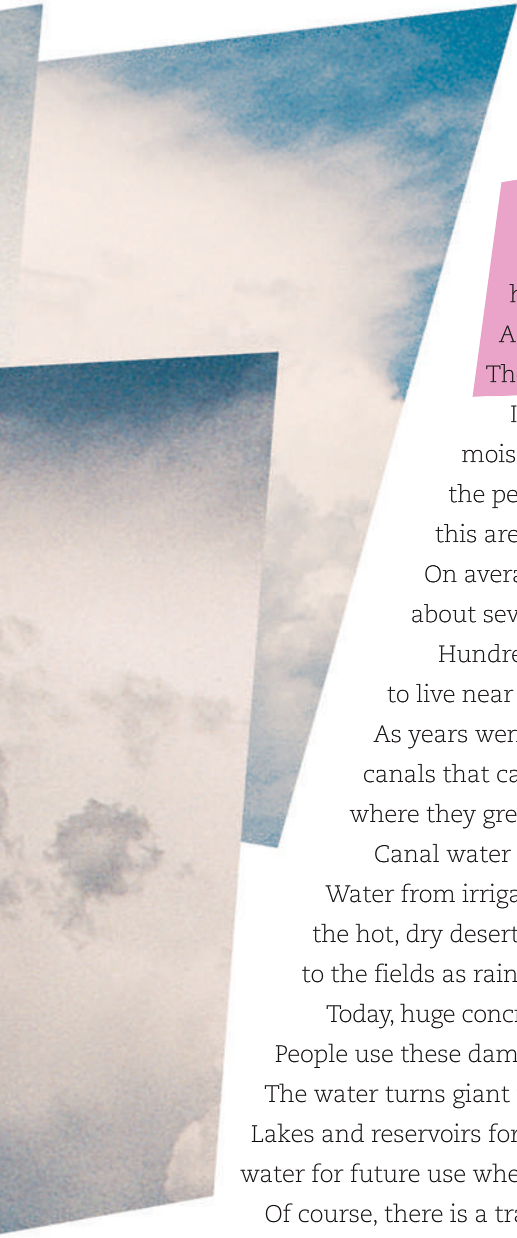
Cool air cannot hold much water vapor. Water molecules begin to stick together as tiny drops or ice crystals. When the drops get too heavy, they fall as rain.

2 . expansion

Atmospheric pressure decreases with height. Without as much pressure squashing in, big bubbles of warm, rising air expand, which causes them to cool.

1 . convection

Warm areas of ground heat the air above them. Warm air is less dense. It floats up through cooler air, just like a cork in a tub of water.



Thunderstorms are like pots of boiling water. Combine water with heat in exactly the right proportions. Add something to stir the mixture. The result is a thunderstorm.

In Arizona's Salt River Valley, getting moisture used to be a real problem for the people who lived here. Today, we know this area as Phoenix and Maricopa County. On average, the entire Phoenix area gets only about seven inches of rain each year.

Hundreds of years ago, native people had to live near rivers if they wanted to survive. As years went by, they learned to design and build canals that carried water from the rivers to areas where they grew crops and built homes.

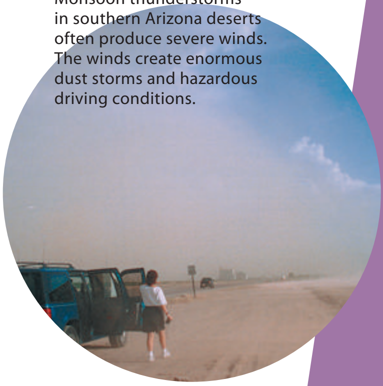
Canal water also helped new rainstorms to form. Water from irrigated fields evaporated quickly into the hot, dry desert air. Eventually, that moisture returned to the fields as rain.

Today, huge concrete dams block many of Arizona's rivers. People use these dams to harness the power of moving water. The water turns giant turbine blades to make electricity. Lakes and reservoirs form behind the dams. The lakes also store water for future use when there is little or no rainfall.

Of course, there is a trade-off. Water is not evenly spread throughout the Phoenix area as it was before the dams were built. Today, Arizona relies on moisture picked up over the Pacific Ocean and Gulf of Mexico to generate rainstorms. That moisture is carried to Arizona by strong wind currents.

Heat is the easiest storm ingredient to find. Arizona gets plenty of heat from a blazing sun that shines nearly every day. During the day, rocks, roads, buildings, and parking lots absorb the sun's heat. In fact, sometimes they absorb so much heat that it actually gets too hot to make a storm. Liquid moisture contained in the air changes to steam before winds can whip up a rainstorm. >>>

Monsoon thunderstorms in southern Arizona deserts often produce severe winds. The winds create enormous dust storms and hazardous driving conditions.



MONSOONS

A monsoon and a thunderstorm are not the same thing. The word monsoon actually comes from an Arabic word which means season—in this case, the summer season.

Arizona's monsoon winds blow from the south during the summer months, bringing air loaded with moisture from the Gulf of California and the Gulf of Mexico. Blend that moisture in exactly the right proportions with heat and wind, and the result is a thunderstorm almost every time.

During the rest of the year, winds blow in to Arizona from the west and northwest. Those winds cause different kinds of thunderstorms.

The longest monsoon season ever in Arizona was in 1984. That year, there were 72 consecutive monsoon days, lasting from June 25 to Sept. 4.

A monsoon requires hot weather and moist air. The dew point, which is the temperature to which air must be cooled for water vapor to condense into water, must be at least 55 degrees Fahrenheit for a true monsoon.

Before the days of television weather forecasters, members of Arizona's Native American tribes said that the monsoons would begin about a week after the cicadas began to sing at night.

Navajo weavers are influenced by the power of Arizona thunderstorms. This rug was made by Rebecca Tso. It is her interpretation of the "storm" pattern.

Dust Devils

Dust devils look like miniature tornadoes. They actually are very different. Tornado winds begin high up in the clouds. Dust devils begin directly on the ground. Dust devils occur when patches of ground get very hot. The hot ground causes air directly above to heat up rapidly as well. The heated air then rises, bangs together, and begins to spin. The result is a whirling column of hot air that sucks up dust and dirt. Dust devils can grow hundreds of feet tall. The fastest dust devils spin at about 40 miles per hour. Not even close to tornado speeds. Tornado winds spin at speeds up to 310 miles per hour.

When water and heat are present in large enough quantities, wind can stir the pot to form a thunderstorm. Hot air rises. Certain structures can make normally gentle air rise fast enough to "stir" the thunder pot. Mountains are one such structure. Rocks and mountains store heat. As a result, mountains and the air around them are usually much hotter than non-rocky areas. Air glides across these non-rocky areas until it bumps into hot mountains. That bump starts the stirring process. Hot mountain air pushes cooler air upward at rapid rates. This is one reason that many Arizona thunderstorms begin in the mountainous Mogollon Rim area northeast of Phoenix.

Local parking lots and small hills can cause smaller rainstorms. During such a storm, for example, it might be raining at your house yet be perfectly sunny at a friend's house located just a half a mile away.

TORNADOES

Monsoon storms can cause a great deal of wind and rain damage in Arizona. But the most destructive wind of all belongs to the tornado. Arizona rarely gets real tornadoes. Tornadoes usually occur under the jet stream. The jet stream is found high in the sky—at about 36,000 feet—which is where most jet planes fly. The jet stream is a powerful, fast-moving river of air that is similar to the air current that blasts from your portable hair dryer. Inside this stream air jets along at 150 to 200 miles per hour.

Air moving that fast can act like a big vacuum cleaner. It sucks up huge pockets of air from ground level. Combine that force with the right proportions of heat and moisture and tornadoes could result. Tornadoes are also called twisters. That's because air from different directions gets sucked up at the same time. When those currents bang together they can cause the air to twist at up to 310 miles per hour. That's faster than even the fastest Indianapolis 500 cars. No "Indy" car has yet reached speeds of 250 miles per hour.

Microbursts

Although Arizona rarely gets twisters, it does get some microbursts. Microbursts can be just as deadly as twisters. Think of microbursts as air bombs. They're blasts of air that begin high up in the clouds and explode straight down. Microbursts form when raindrops become so heavy that they force the air they are falling through to fall with them. That air can fall at speeds of 90 miles per hour. Air inside normal storms falls at about 10 miles per hour. When microbursts hit the ground, they pick up dust and shoot it out and up. The resulting blast pattern looks similar to that which would be caused by a nuclear bomb.

Bolts from the Sky

Lightning is actually static electricity. Static electricity is very much like the sparks you get when you walk across a carpet and touch something. However, nature creates much more static electricity than all the rugs and carpets in the world combined.

Lightning forms when rain falls through clouds. As rain droplets fall, they tug electrons down through the clouds with them. Electrons are the tiny parts of an atom that have negative electrical charges. Nature likes to maintain a balance. So, when electrons get pulled out of place, nature wants to put them back. That is exactly what lightning does.

Raindrops pull down electrons. But their proton partners get left behind in the upper part of a cloud. Protons are the tiny parts of an atom with a positive electrical charge. Protons and electrons are attracted to one another, just like magnets.

Photos: NOAA; iStock

Lightning Flashes

- **Every single second, a hundred bolts of lightning are striking towards the Earth. At any given moment, there are 1,800 thunderstorms in progress all over the world.**
- **The saying "lightning never strikes twice" is not really true. Lightning is very likely to strike the same place twice. Like all electric currents, lightning follows the path of least resistance.**
- **Lightning kills more people around the world than any other natural disaster. An average of 400 people die and 1,000 are injured by lightning every year.**
- **Arizona's mogollon rim area has one of the highest incidences of lightning strikes of any place in the world!**

Fact: A bolt of lightning is charged with about 1 billion volts of electricity. That is enough energy to light a 100-watt bulb for three months.

Photo: Jim Marshall

Lightning occurs when lonely electrons seek out nearby protons to recreate balance. Those protons might be resting at the top of another cloud. They can also form along the ground under the cloud. When protons are pulled from another cloud, the result you see is cloud-to-cloud lightning. But when the protons are pulled up from somewhere on the ground, the result is a lightning strike.

Well, not really. Lightning does not actually "strike" the ground. It stops about 50 feet above the ground. When downward flowing electrons meet upward flowing protons, they complete an electrical circuit. That circuit is much like the connection that forms when you plug in a CD player to an electric outlet and turn on the switch.

Lightning is actually a gigantic flow of electrons through the circuit that is completed in the air. On the ground, the protons closest to the downward flowing electrons will be pulled upward to complete the circuit. Those protons might be part of a tree, or part of a person standing in the middle of a golf course fairway.

Protons are drawn upward from the highest point closest to the electrons. That is why a person should never stand in a field or hide beneath a tree during a thunderstorm.

If you were the highest point closest to the flowing electrons in search of positive partners, the protons inside your body would begin to flow upward. Your hair, which contains protons, would stand straight up on end as those protons reach skyward. About 50 microseconds late—before you could even blink your eye—the circuit would be completed and you would be electrocuted.

LIGHTNING IN A JAR The Leyden Jar was one of the earliest electrical devices. It works in a similar way to the modern device called a capacitor. Early experimenters found they could build up a charge of static electricity in the jar—enough to cause a nasty shock!

Thunder above

If lightning is considered a completed electrical circuit, then what the heck is thunder? Thunder is caused when that electrical circuit—lightning—is formed. Air surrounding a lightning flash is superheated almost instantly. In fact, the air around a lightning bolt is five times hotter than the surface of the sun.

The superheated air expands so quickly that it explodes, just like a bomb. The blast, or shock wave, moves outward from the point of the explosion. That shock wave has a name. It is called thunder.

Because sound travels much more slowly than light, we hear the thunder after we see the lightning's flash.

Higher is hotter?

Temperature is different from heat. Molecules of any substance, like oxygen or nitrogen in the atmosphere, jostle around according to the energy they possess.

Higher temperature means more jostle—like shaking a box of ping-pong balls faster and faster. Temperature tells the speed of molecules as they shake.

Heat is energy. The amount of heat depends on temperature and density—a measure of how heavy the molecules are and how tightly they pack together. Think of the difference between shaking a box of ping-pong balls and a box of marbles.

The air of the thermosphere is thin. Although the temperature is very high in the thermosphere and the molecules are moving fast, there are very few molecules present. If you could stand outside in the thermosphere, 50 miles above the surface of the Earth, you would freeze rather than boil!

CATALYSTS make things happen. They speed up reactions and make some ingredients combine that could not without them.

catalyst

What is atmosphere?

Atmosphere is the huge blanket of gas that circles the entire Earth. Without it, life as we know it could not exist.

This blanket of gas starts at ground level and stretches 600 miles into the sky. However, most of this life-supporting shell is squashed down into a layer only six miles thick. The top of Mount Everest barely peeks above the edge of this layer.

The remaining 594 miles cannot support life. However, these layers do protect us from the dangers of the sun's radiation. They also protect us from drifting rocks, big hunks of metal, and other bits and pieces of space junk that collide with our planet from time to time.

The atmosphere is made of four different layers. Layer number one is called the troposphere. People, plants, animals, and insects live in the troposphere. It is the layer where all weather occurs.

Scientists who study weather are called meteorologists. They refer to the troposphere as "The Weather Zone." The troposphere begins at ground level and extends six miles up into the sky where it meets with the second layer.

Layer number two is called the stratosphere. The stratosphere begins at the six-mile point and reaches nearly 31 miles into the sky.

A very important layer of atmosphere called ozone is located inside the stratosphere. The ozone layer is very important to all life on Earth. Ozone blocks large amounts of solar ultraviolet radiation from entering the troposphere. Too much solar radiation can harm living things, including people.

The third major layer is the mesosphere. The mesosphere begins 32 miles above the Earth's surface. Temperatures are warmest at the lowest level of the mesosphere and become colder at its highest level.

The thermosphere is the fourth layer and begins 50 miles above the Earth. Temperatures in the thermosphere become hotter and hotter when moving farther away from ground level.

Together, the troposphere, stratosphere, mesosphere, and thermosphere act as a giant safety blanket. They keep the temperature on the Earth's surface from dipping to extreme icy cold that would freeze everything solid, or from soaring to blazing heat that would burn up all life.

UP TO 600 MILES
THERMOSPHERE

UP TO 50 MILES
MESOSPHERE

UP TO 31 MILES
STRATOSPHERE

UP TO 6 MILES
TROPOSPHERE

Why is the sky blue?

White light is made up of all seven colors found in the rainbow. When pure sunlight shines through the weather zone, water droplets and other moisture refract, or bend, the light. The refraction of pure sunlight causes the sky to appear blue.

Scientists call this "weather zone" the troposphere. This important part of the atmosphere is made of mostly nitrogen and oxygen. About three-fourths of the troposphere is nitrogen. Less than one-fourth is oxygen, or just about 21 percent. The remaining 1 percent is made of a gas called argon, and tiny traces of other gases.

When pure sunlight shines through these gases, blue light is scattered in all directions, and some bounces toward your eyes. A deep blue sky means that there is very little moisture in the troposphere.

A pale blue sky, or a gray sky, means there is lots of moisture in the weather zone. That is why gray skies are usually rainy skies.

Refraction, reflection, scattering:

We see colors because light of that color enters our eyes. Things have color because they are made of material that reflects or transmits only certain colors of light. An opaque red material, for example, absorbs most light except red. Light reflects from the surface of opaque material, but refracts at the surface of transparent material. Refraction means light's direction of travel bends as it passes through the surface, depending on the material and color of the light. Blue light bends more than red.

Light of all colors is scattered by an irregular bunch of refractions and reflections. Clouds appear white because they are made of jumbled tiny water droplets and dust.

If the Earth was reduced to the size of an apple, the atmosphere would be only about as thick as the skin.

Who is Roy G. Biv?

Roy G. Biv is a rainbow.
To remember the order of colors you see in a rainbow, always think of Roy. Each letter in his name represents a color of the rainbow. Use the first letter of each color and you spell his name: Red, Orange, Yellow, Green, Blue, Indigo, and Violet. These colors always occur in the same order. Red is always first. Violet is always last. Rainbows always occur in the sky on the side opposite the sun. If you are flying in an airplane and see a rainbow, you most probably will see it as a full circle, not just a bow.

Illustration: Michael Hagelberg

Meet clouds by name

Clouds can make us happy. Clouds can make us sad. Big puffy white clouds floating through a bright blue summer sky make us smile. But boiling black storm clouds slashed with jagged lightening and crashing thunder make us run for shelter. ✻ To be precise, a cloud is nothing more than a collection of water particles or ice crystals floating in the atmosphere. There are 10 different types of clouds. In 1803, English pharmacist Luke Howard identified these distinct cloud types. He then devised a system of cloud classification. ✻ Howard's cloud classification system uses Latin words that describe the placement (high) and appearance (spread out) of clouds. For example, using Howard's system, a high (alto), spread out (stratus) cloud is called an altostratus cloud. ✻ Meteorologists still use Howard's system today because it is so simple and effective.

HIGH Clouds forming in high-altitudes are called cirrus, cirrostratus, and cirrocumulus. It is so cold in the upper atmosphere that high altitude clouds contain ice crystals instead of water particles.

CIRROCUMULOUS clouds look like upside down waves rolling across the sky.

High, thin **CIRROSTRATUS** clouds look much like stratus clouds, but cirrostratus clouds contain ice crystals and are much higher.

CIRRUS clouds form when the wind blows these ice crystals into wispy streaks that look like thin horse tails.

MIDDLE Altocumulus and altostratus are middle-altitude clouds. Even though the word alto means "height" in Latin, these are not the highest clouds.

ALTOCUMULUS clouds look fleecy and have dark, shadowed sides.

ALTOSTRATUS clouds are flat and make the sun look as if it is being seen through a misty glass.

LOW Five of the 10 types of clouds can be found at low altitudes. The low-altitude clouds are called cumulonimbus, cumulus, stratus, stratocumulus, and nimbostratus.

CUMULONIMBUS clouds are piled up high like scoops of dark ice cream. These clouds usually bring rain showers.

CUMULUS clouds look like giant heads of cauliflower because they are white and fluffy.

STRATUS clouds are spread out, dull clouds usually found at ground level. Stratus clouds may so close to the ground they are identified as fog.

STRATOCUMULUS clouds are spread out heaps of dense cover that rise higher in the atmosphere.

Dark, flat **NIMBOSTRATUS** clouds often produce rain or snow.

Cloud photographs courtesy Mohan Ramamurthy, Ph.D., Dept. of Atmospheric Sciences, University of Illinois at Urbana-Champaign, and the National Center for Atmospheric Research, Boulder, Colorado.

Air and water

Relative humidity can be measured using two thermometers. Wrap one thermometer bulb with cotton gauze that is soaked with water. The other bulb is kept dry. The dry-bulb thermometer measures the temperature of the air. The wet-bulb thermometer is cooled by water evaporating from the wet gauze. If the air is dry, the water evaporates faster. This cools the wet-bulb more than the dry bulb. As a result, the temperature is lower on the wet bulb compared to the dry bulb temperature. The drier the air, the faster the evaporation. That means the cooler the wet-bulb temperature will be. If the air is humid, the water evaporates slowly, if at all. The wet-bulb cools slowly. The result is a temperature much closer to the dry-bulb temperature. The difference between the dry-bulb and wet-bulb temperatures indicates the relative humidity.

Wind Makes Weather Wind can be many things. A gentle breeze on a warm spring day is welcome and soothing. But the powerful swirling winds of a tornado or hurricane hold some of nature's most powerful destructive force. Breeze or gale, wind is really nothing more than hot and cold air in motion. The world's winds are part of a global system of air circulation that moves light hot air toward the poles and the heavy cold air toward the equator. When cold air meets hot air, the cold air is sucked under the rising hot air. A low pressure front is created. Low-pressure zones are characterized as wet and stormy weather. These zones come with gray skies and high winds. Winds blow wherever there is a difference in air temperature and pressure.

Meteorology and Climatology are not the same!

Scientists like facts. They use terms that mean specific things. When studying weather, you should know that meteorology and climatology are not the same thing.

Meteorology is the study of our atmosphere. The focus is on tracking and predicting weather patterns. Climatology is just one branch of meteorology. The focus is on the origin of atmospheric patterns observed over a period of time.

Meteorologists watch the development of storms and record daily temperatures. Meteorologists also provide the National Weather Service with warnings about severe weather and storms. Their job also is to inform the public about the same storms.

The climatologist's work is a bit different. A climatologist might compare modern hurricanes with hurricane activity that took place hundreds of years ago. He looks for similarities and differences. If there is a difference, the climatologist will try to discover reasons for the change and how it will affect future hurricanes.

POWERING THE WEATHER

The weather is powered by energy in many forms. Lightning is electrical energy. Thunder is sound energy. The wind involves kinetic energy. Gravity plays a role as well. Gravity causes cold air to fall and hot air to rise through a process called convection. Convection creates wind.

QUESTION: **Lots of people say that they can see shapes formed in the clouds. But exactly how do clouds form into shapes?**

PROFESSOR CERVENY: **The process of cloud formation is called "cloud physics." It's a pretty complex subject. But think about it this way. Clouds form as bubbles of moist air. Those bubble rise and then cool to the point that the water condenses out. In other words, the water changes from being a vapor, like steam, and becomes a liquid—water. Dry air sinks around the bubbles. That creates irregularly shaped bubbles that form different shapes. But those shapes are just accidental. They don't have any meaning other than being pretty to look at. A cloud is really just a big bubble of rain that hasn't fallen to the ground yet.**

Cloudy answers

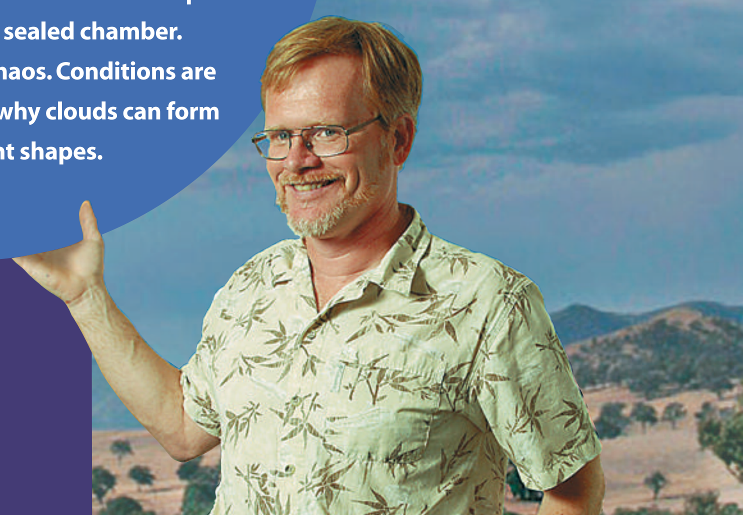
Randy Cerveny is a climatologist at Arizona Stataiversity. He is a President's Professor in the School of Geographical Sciences. That means he is a very smart guy. Cerveny knows all about clouds and lots of other interesting weather stuff. That's his job. He studies weather and climate and then teaches others about what he learns. Students always have lots of questions for the professor. Want to learn something about clouds? Keep reading:

QUESTION: **I know that clouds are formed by molecules of water that get all smooshed together. But why do they form different shapes?**

PROFESSOR CERVENY: **The answer is air. Air currents, to be exact. Air currents are constantly pushing clouds up and down. Different layers of the air have different amounts of water in them. Cloud shapes shift and change as the air pushes them in different directions.**

QUESTION: **But wouldn't all the molecules squeeze together? Then all the clouds would be one shape, and only one shape. Why don't clouds all look like a circle or an oval?**

PROFESSOR CERVENY: **If you were to form a cloud in a nice sealed chamber where you keep constant conditions (winds, temperature and humidity) inside, you would be right. Every cloud would form into the same shape. But our world is not a sealed chamber. Nature contains lots of chaos. Conditions are always changing. That is why clouds can form lots of different shapes.**



QUESTION: **I notice that some clouds are thinner than others. That's because some clouds contain lots more water than others. But why don't the clouds break apart and become smaller?**

PROFESSOR CERVENY: **The key is how high up you push the clouds. All air contains water. But if you push some of that air up high enough (to where it is colder), that water condenses out from vapor (steam) to liquid (water). We see the liquid as a cloud. How high up a cloud gets pushed and how much water vapor it contains are the important factors that determine how thick a cloud will be.**

QUESTION: **How do clouds stick together? What holds the water molecules together?**

PROFESSOR CERVENY: **Sometimes they don't. When the water droplets get heavy enough, they fall out of the cloud. We call that rain.**

QUESTION: **How fast do clouds really move?**

PROFESSOR CERVENY: **That depends on how fast the winds are blowing around and above the clouds. On nice calm days, the puffy cumulus clouds we see are not moving at all. However, some storm clouds can move at 60 or 70 miles per hour.**

QUESTION: **What would our weather be like if the Earth was shaped like a square instead of a round sphere?**

PROFESSOR CERVENY: **A square-shaped planet with an atmosphere would not exist for very long as a square. It would quickly become round-shaped. The power of weather plus time is very strong. It might take millions of years, but the power of wind, water, and heat would cause the "edges" of the cube to be rounded. Just like a square pebble or rock in a river gradually becomes rounded. Or think about mountains as an example. Mountains are built quickly (geologically-speaking). But over time, the power of weather erodes the even the tallest, sharpest mountains into smooth, round hills. Mother Nature prefers a nice smooth, rounded surface to blow across.**

Who's that storm?

Exactly how do hurricanes get their names?

BY DIANE BOUDREAU

Hurricane Katrina's eyewall swirls in a photograph made by a National Oceanic and Atmospheric Administration P-3 hurricane hunter crewmember on August 28, 2005, a day before the powerful storm slammed into the United States Gulf Coast. (Photograph: NOAA)

Everyone talked about her in 2005. She's so famous she doesn't need a last name. Just mention her name and people stop to listen. Who is this celebrity? Is it Madonna? Is it Angelina? No, it's Katrina. But she's no singer or movie star.

Hurricane Katrina devastated New Orleans in August 2005, killing at least 1,300 people. Katrina caused about $75 billion in damage to the southeastern United States. No one who was alive during this storm will forget the name Katrina. But how exactly did this hurricane get that name to begin with?

Randy Cerveny is a climatologist at Arizona State University. He says the hurricane naming system began in the 1800s. An Australian man started naming storms after politicians he didn't like.

The U.S. Air Force began formally naming storms in the 1950s. They used the names of pilots' girlfriends. The World Meteorological Organization (WMO) later took over the process. Officials at the WMO created six lists of names for each region. Each list contains 21 names. The lists start with each letter of the alphabet except for Q, U, X, Y and Z. At first, the WMO only used female names. Public protest made them change the system in 1979. Since then, they have alternated male and female names.

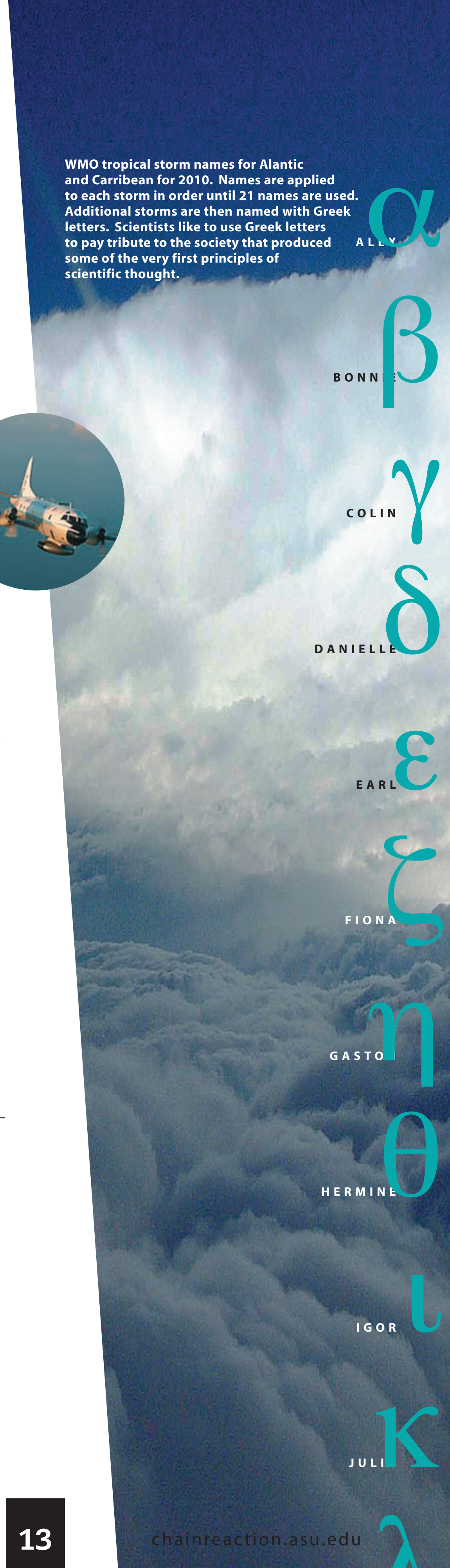
The first storm of the season always starts with A. After that, the storm names follow the list in alphabetical order. If there are more than 21 storms in a season, any extra storms will be named using the Greek alphabet: Alpha, Beta, etc.

After going through all six lists the WMO goes back to the first list and starts over again. If a storm is particularly destructive, its name gets retired, just like a famous athlete's jersey number. For example, there will never again be another Hurricane Katrina.

The WMO naming system is not used everywhere on Earth. For example, on the east coast of Asia they use the names of flowers and old gods. But everywhere you go, people want to give storms some kind of name. "The reason we name hurricanes is because people pay more attention to a name than a number," explains Cerveny. When people are in danger and need to evacuate a town, getting their attention can be a matter of life and death.

Even the name "hurricane" isn't used everywhere. The general name for all hurricane-type storms is "tropical cyclones." In the Atlantic Ocean, they are called "hurricanes." In the Pacific Ocean they are called "typhoons." Off the coasts of Australia and India, the storms are called "cyclones."

But all these names describe the same weather process. "A hurricane is basically a big heat engine. It pumps hot water from the ocean and converts it to rain and heat," Cerveny says. "Almost all hurricanes start off as a dust storm.



A country created by a storm

The worst tropical storm ever recorded struck a region that was known as East Pakistan in 1970. About 500,000 people died—more than died in the 2004 tsunami. The people of East Pakistan were angry that Pakistan did not send aid quickly enough, so they broke off and formed a new country. Today that country is called Bangladesh. It is the only country created as a result of a hurricane.

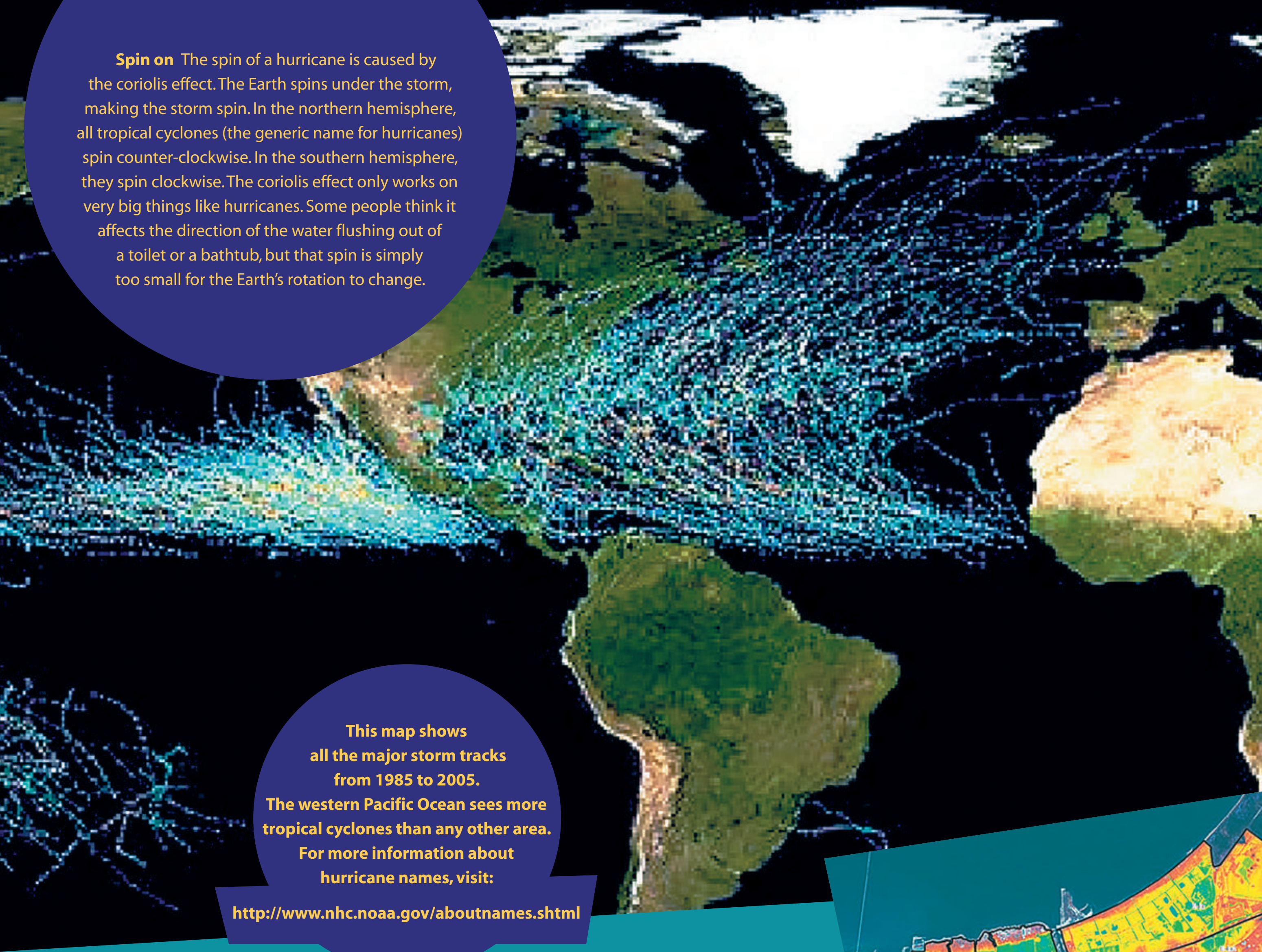
FAST FACTS ABOUT HURRICANES

Winds of more than 100 mph, a tidal surge of 25 feet above sea level and floodwaters from Lake Ponchatrane contributed to the devastation of

Usually they originate in Africa and work their way off the African coast into the Atlantic Ocean. Most fall apart without ever reaching the Americas. A few start to take on a form that causes more development," he adds.

Once a storm reaches 39 miles per hour, it becomes a tropical storm and gets a name. When it reaches 74 miles per hour it qualifies as a hurricane.

Scientists aren't sure why some storms become hurricanes while others die off, but they are trying to learn. As soon as a storm starts to spin, the National Weather Service sends some of the best pilots in the world to fly right through it. This is a risky business. Cerveny hasn't flown through a hurricane, but he has flown through an Arizona thunderstorm in a hurricane hunter plane. "They tell you not to eat breakfast and to take Dramamine (a drug for motion-sickness)," he says. "The plane is basically a modified commercial plane. The seats have been taken out and replaced with computer workstations. Instead of a seat belt you wear a harness. You go up to 50,000 feet and down to about 18 feet off the ground and up to 50,000 feet again. It beats any roller coaster hands down!"



Spin on The spin of a hurricane is caused by the coriolis effect. The Earth spins under the storm, making the storm spin. In the northern hemisphere, all tropical cyclones (the generic name for hurricanes) spin counter-clockwise. In the southern hemisphere, they spin clockwise. The coriolis effect only works on very big things like hurricanes. Some people think it affects the direction of the water flushing out of a toilet or a bathtub, but that spin is simply too small for the Earth's rotation to change.

This map shows all the major storm tracks from 1985 to 2005. The western Pacific Ocean sees more tropical cyclones than any other area. For more information about hurricane names, visit:

http://www.nhc.noaa.gov/aboutnames.shtml

The planes drop instruments into the storm to get information. Scientists also use satellite data for information. "But we still need people willing to risk their lives and fly through the middle of these things," Cerveny says. "Each time we do we learn new stuff and our forecasts get better."

Most damage from a hurricane comes from what is called the "storm surge." A hurricane's low pressure sucks up water from the ocean, lifting it above sea level. Then the water floods over the land. During hurricane Katrina, the worst of the storm surge was 25 feet high. "It's like a big bubble of water under the hurricane. It's kind of like a tsunami but it's not just one wave that comes in and recedes. It just keeps coming in underneath the hurricane," says Cerveny. "One foot of water moving at 10 miles per hour can move a Hummer."

Hurricanes generally don't affect Arizona, but in 1997, Hurricane Nora hit the Pacific coast and caused about 5 inches of rain in Yuma. "They were actually sandbagging and teaching people how to tape their windows," says Cerveny. "It dried out before it got to Phoenix. It was very odd."

Scientists at the National Oceanic and Atmopheric Administration were able to make accurate forcasts of the path of Hurricane Katrina. Unfortunately that path led almost directly to the city of New Orleans which suffered terrible floods as a result. This map shows the water depth covering the city. Green areas mark depths of 7 to 8 feet, yellow areas 4 to 5 feet.

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.

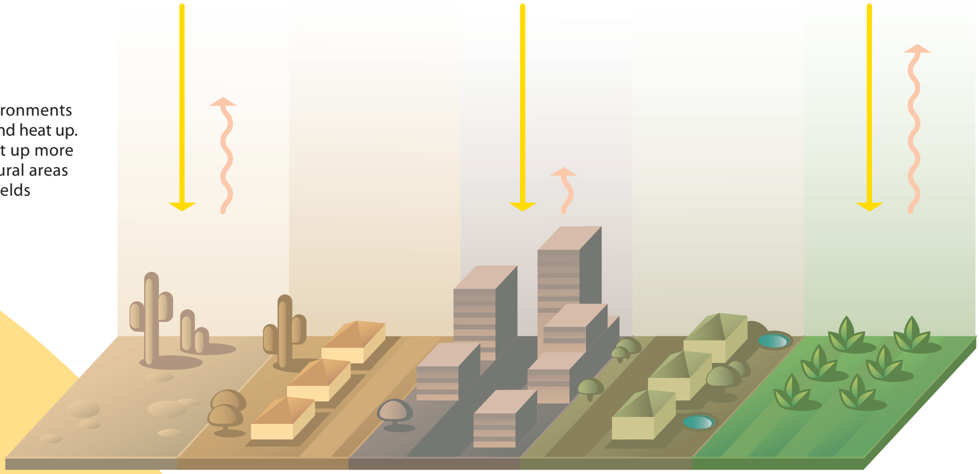
Agricultural areas are cooler than natural desert, Brazel says. This is because farms have a lot of water and plants. When water evaporates, it lowers the temperature of whatever is around it. For example, your body cools off when your sweat evaporates.

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.

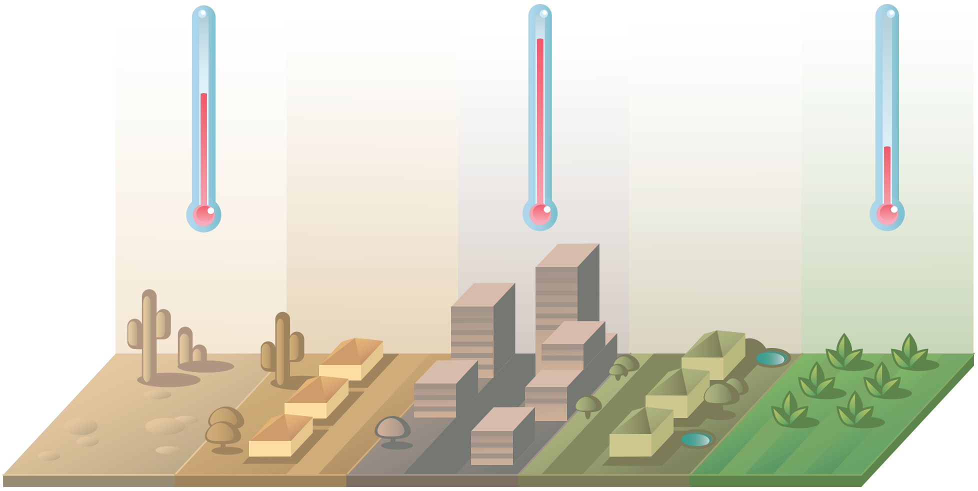
On the other end of the spectrum is vegetation—good old green plants. The sun's energy goes into evaporating the water that these plants receive, not into the ground. The researchers are finding out that neighborhoods with more plants and more water (such as swimming pools) are cooler than neighborhoods 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.

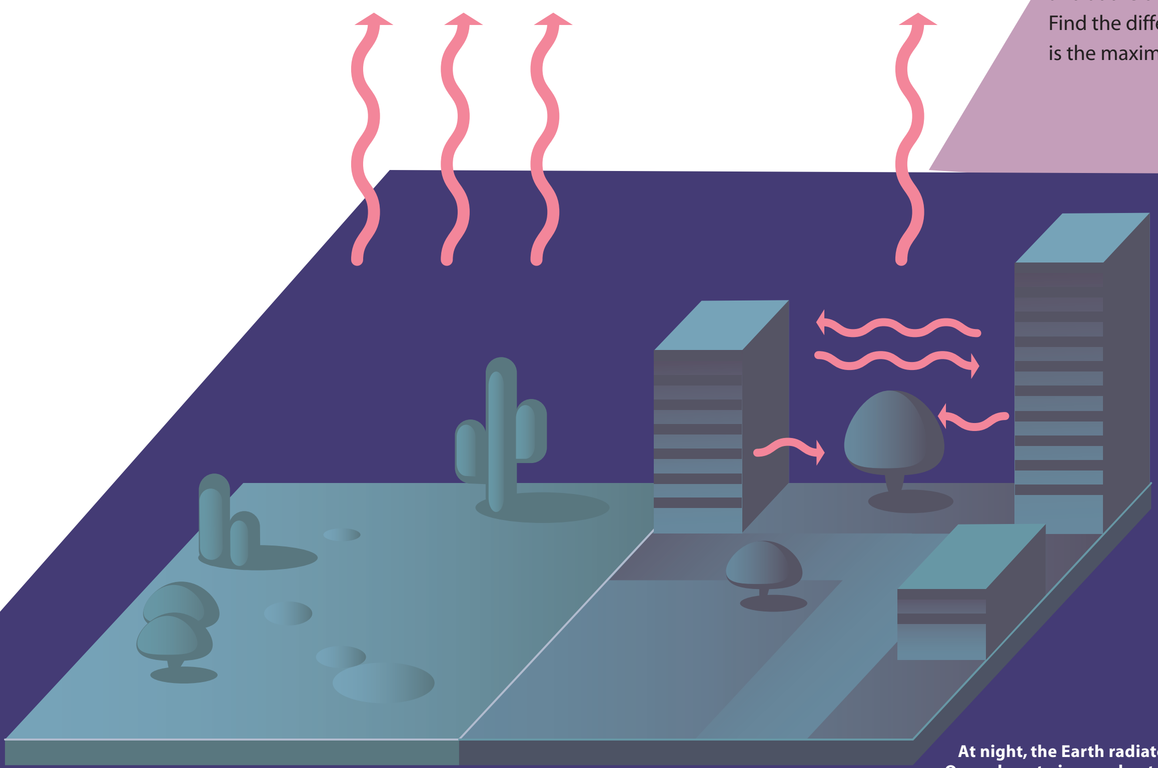
The way buildings are arranged can also have an effect on heat islands. Brazel talks about "urban canyons," created when you place tall buildings along narrow streets. The buildings provide shade and create cooling wind patterns. "The city of Phoenix was planned long ago," says Brazel. "It has wide streets 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.

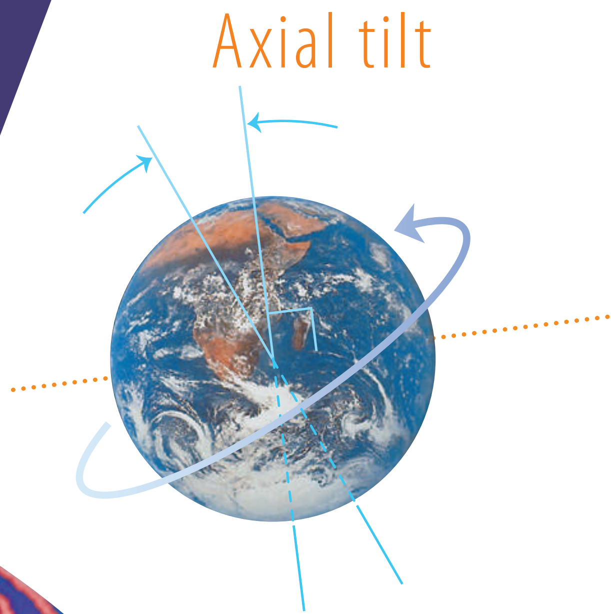
The maximum heat island: Many things can affect a city's temperature besides the heat island effect. Wind, clouds, and rain all confuse the issue. When people want to know what effect the city alone has on temperature, they measure the maximum heat island. Choose a calm, sunny day with no wind, no clouds, 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.

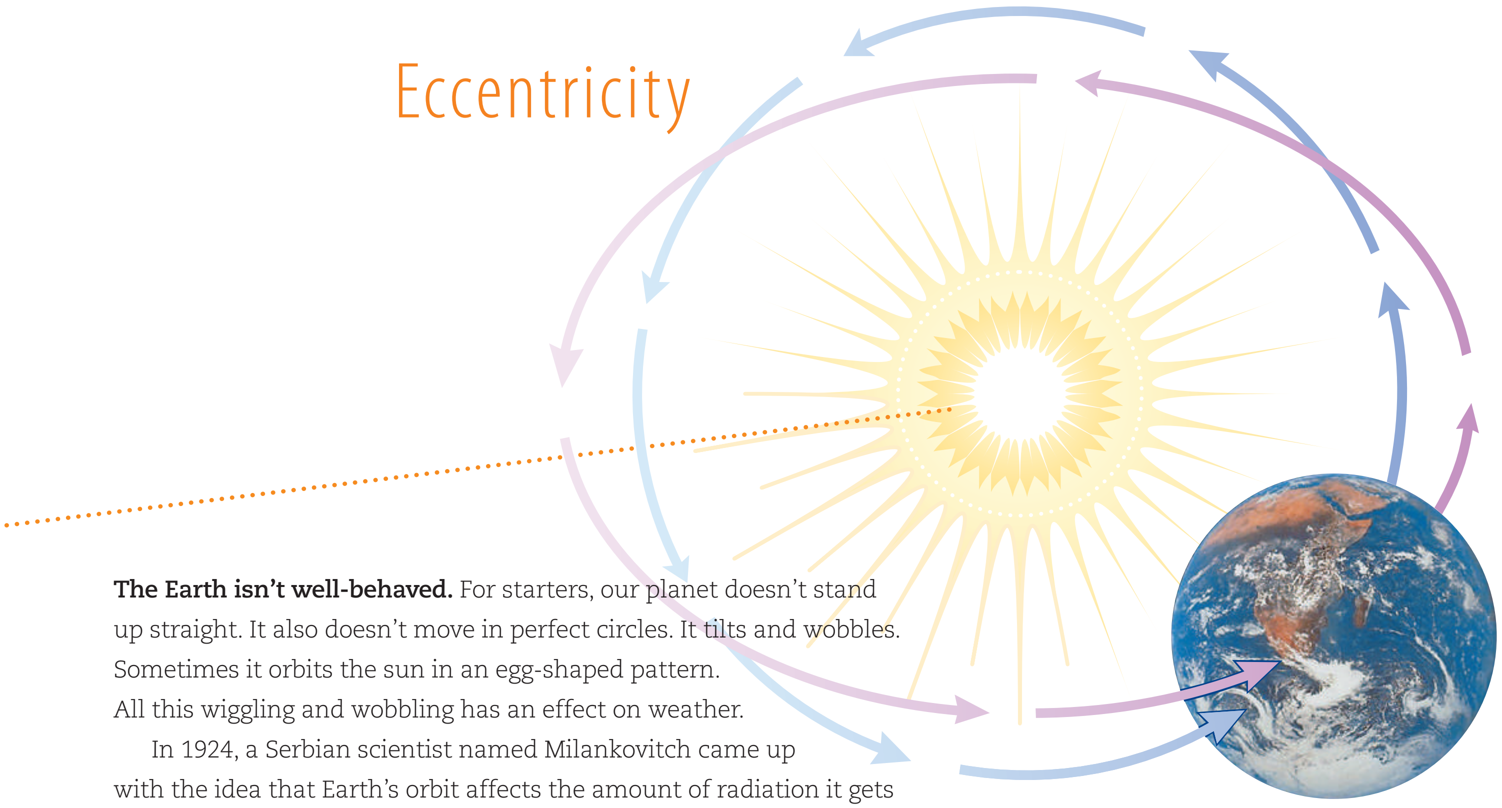
ToPSY TURVY EaRTH

BY DIANE BOUDREAU



This is a computer model of the Earth created by former ASU graduate student John Shaffer. The model is based on how the Earth moves in space. It calculates and maps the amount of sunlight reaching the surface for separate zones of latitude. Results show how much sunlight arrived for any time thousands of years into the past.

Eccentricity



The Earth isn't well-behaved. For starters, our planet doesn't stand up straight. It also doesn't move in perfect circles. It tilts and wobbles. Sometimes it orbits the sun in an egg-shaped pattern. All this wiggling and wobbling has an effect on weather.

In 1924, a Serbian scientist named Milankovitch came up with the idea that Earth's orbit affects the amount of radiation it gets from the sun. The changes in radiation affect Earth's climate. In particular, they dramatically affect the big ice sheets we call glaciers.

The Milankovitch Theory uses three characteristics of Earth's orbit to find out how much solar radiation the planet receives. These three characteristics are eccentricity, axial tilt, and precession.

Eccentricity describes the shape of Earth's orbit. Earth revolves around the sun, but it doesn't always move in a perfect circle. Over a period of 100,000 years, Earth's orbit slowly changes from circular to egg-shaped and then back to circular.

The second characteristic is called axial tilt. Imagine a straw pushed through the center of an orange. When the straw is straight up, the orange doesn't tilt in any direction. But if you tilt the straw at an angle, the orange tilts in the same direction.

The same thing happens with the Earth. The "straw" is Earth's polar axis—an imaginary line that runs from the North Pole through the planet to the South Pole. As Earth orbits the sun, the axis is never straight up and down. It always tilts at a small angle.

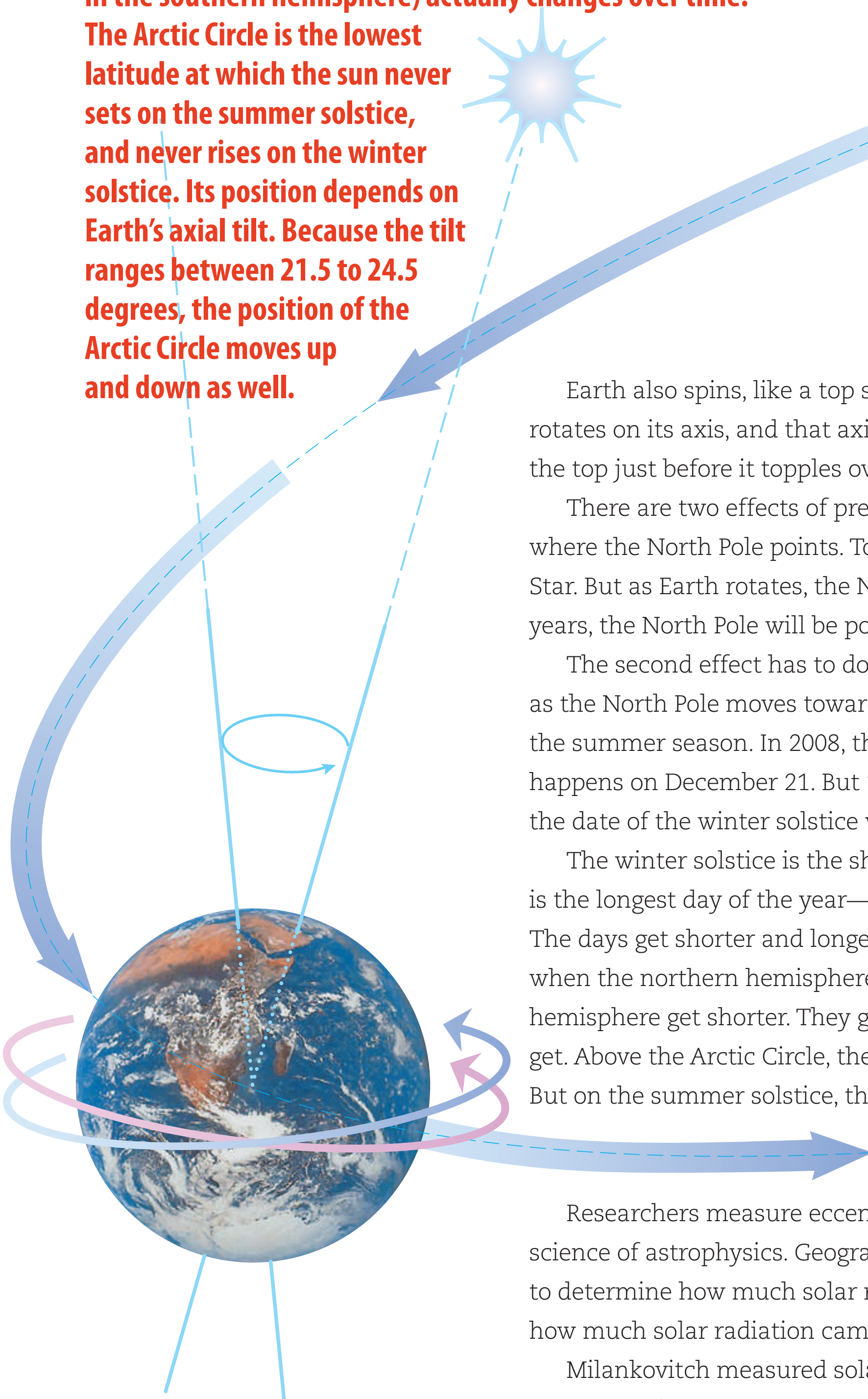
Picture a line drawn from the center of the sun to the center of Earth. The polar axis crosses this line. If the axis were straight up and down, these two lines would form a right angle (90 degrees). In reality, these two lines make an angle greater than 90 degrees because of the axial tilt. Currently, Earth's axis tilts about 23.5 degrees beyond the center. Over long periods of time, this angle ranges from 21.5 to 24.5 degrees.

Four hundred years ago, in 1609, Johannes Kepler worked out a theory to describe the motion of planets as they orbit. He discovered that the orbits of the planets follow ellipses—sort of football-shaped squashed circles. In fact, no planet can have a perfectly circular orbit, but Kepler did not know that. He did not understand that gravity holds planets in orbit around the sun, and propels them in their elliptcal orbits. Issac Newton figured out this connection by 1687, and said:

$$F = G\frac{m_1 m_2}{d^2}$$

(IT MEANS THE FORCE OF GRAVITY BETWEEN ANY TWO OBJECTS IS PROPORTIONAL TO THEIR MASSES DIVIDED BY THE SQUARE OF THE DISTANCE BETWEEN THEM).

The position of the Arctic Circle (and the Antarctic Circle in the southern hemisphere) actually changes over time. The Arctic Circle is the lowest latitude at which the sun never sets on the summer solstice, and never rises on the winter solstice. Its position depends on Earth's axial tilt. Because the tilt ranges between 21.5 to 24.5 degrees, the position of the Arctic Circle moves up and down as well.



Precession

Earth also spins, like a top spinning across the floor. Because Earth rotates on its axis, and that axis is tilted, the Earth's spin is wobbly. It is like the top just before it topples over. This wobbly motion is called precession.

There are two effects of precession. First, the wobbling motion changes where the North Pole points. Today, the North Pole points toward the North Star. But as Earth rotates, the North Pole moves across the sky. In 11,000 years, the North Pole will be pointing toward a star called Vega.

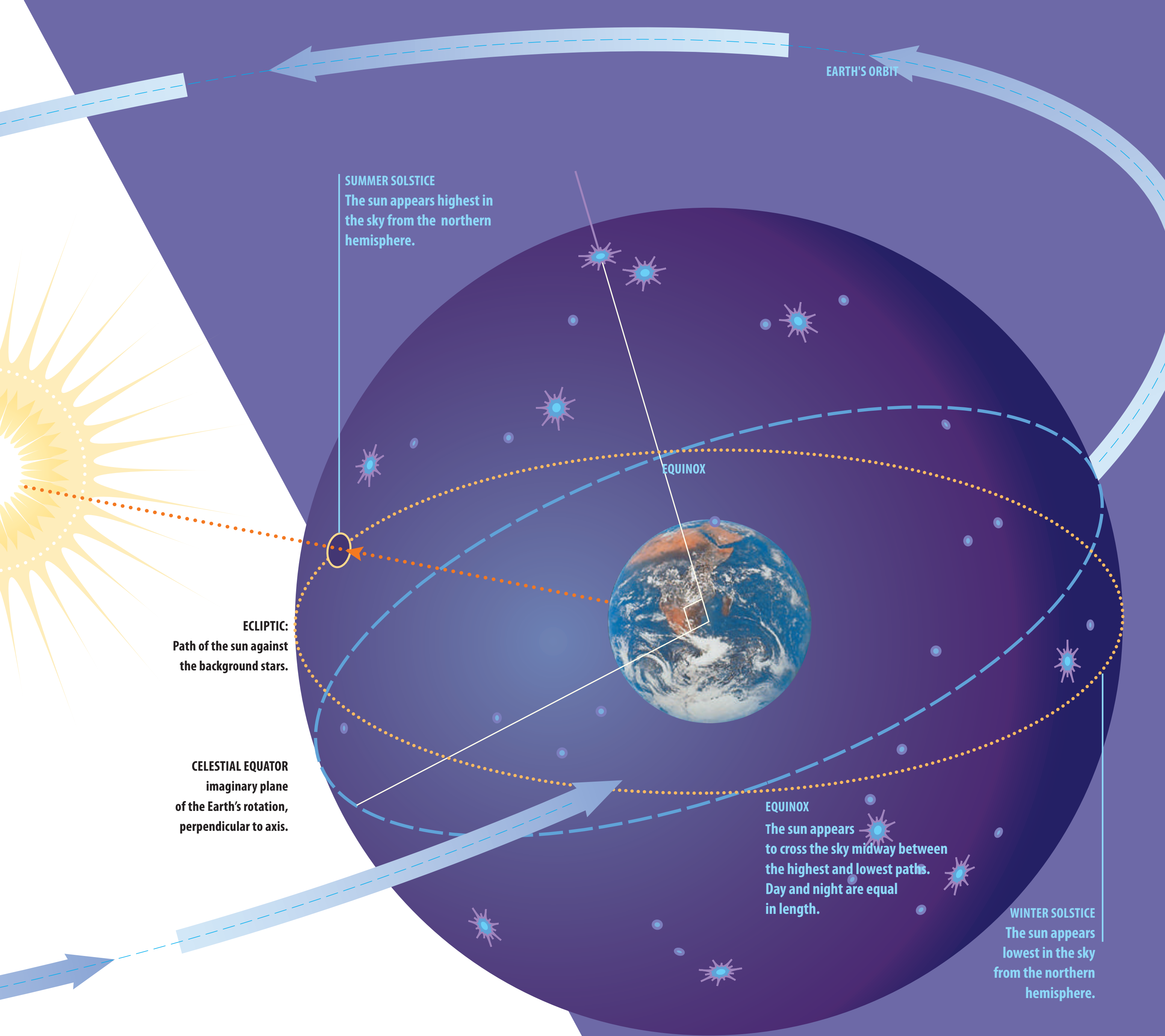
The second effect has to do with seasons. During the next 11,000 years, as the North Pole moves toward Vega, today's winter season will become the summer season. In 2008, the winter solstice in the northern hemisphere happens on December 21. But 11,000 years from now, in the year 12,198, the date of the winter solstice will be June 22!

The winter solstice is the shortest day of the year. The summer solstice is the longest day of the year—the day with the most hours of sunshine. The days get shorter and longer because of the Earth's tilt. For example, when the northern hemisphere tilts away from the sun, the days in that hemisphere get shorter. They get shorter and shorter the further north you get. Above the Arctic Circle, the sun doesn't rise at all on the winter solstice. But on the summer solstice, the sun doesn't set.

Researchers measure eccentricity, axial tilt, and precession using the science of astrophysics. Geographers and climatologists use these numbers to determine how much solar radiation Earth receives today. They also study how much solar radiation came to the planet in the past.

Milankovitch measured solar radiation during the summer. He had good reason. During the summer, solar radiation affects how fast ice sheets grow or melt. Low solar radiation during the summer keeps temperatures cool and helps glaciers to grow.

Of course, wet winters also are important to growing glaciers. Increased solar radiation during the winter causes rain and snow. The rain and snow fall on top of the ice sheet. When they freeze, the glaciers grow bigger.



Celestial sphere

The sun is about 93 million miles– 150 million kilometers– from the Earth. The next closest star is about 280 thousand times farther away. The Earth's orbit is so small compared to that distance that the stars are considered "fixed" in the sky. That is, the stars do not appear to move on the celestial sphere as the sun and planets do.

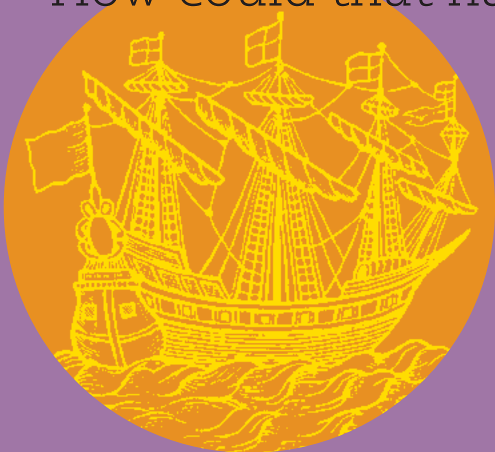
Illustration: Michael Hagelberg

The opposite conditions cause ice sheets to melt. No ice builds up on the glacier if it does not rain or snow during the winter. High solar radiation during the next summer means warmer weather. A warm summer makes ice melt off the glacier.

When Milankovitch thought up his theory in 1924, he had to do the math by hand. It took days to figure out the total amount of incoming solar radiation. Milankovitch didn't have time to study the entire planet.

Today's scientists have computers that can do the math much faster than people can. As a result, they can now study the entire planet.

In 1492, the Niña, Pinta, and the Santa Maria set sail during the peak of the hurricane season. Amazingly, Christopher Columbus and his small fleet did not come across a single hurricane. How could that happen?



Climatologist Randy Cerveny has answers. He compared the route Columbus sailed with historical hurricane data collected during this century. "Notorious modern hurricanes such as Gilbert and Hugo were spawned during September and October," says Cerveny, President's Professor of Geographical Sciences at Arizona State University. "Yet, according to Columbus' logbooks, he and his ships failed to meet with even nominally severe weather.

"Columbus' odds of meeting a big hurricane were less than one per century. He was a lucky sailor. He chose an incredibly favorable course—the best possible to avoid hurricanes," Cerveny says.

After discovering America, Columbus spent several years exploring Caribbean islands. It seems likely that a hurricane would have crossed the explorer's path at some point. More hurricane activity begins in the Caribbean than in the Atlantic Ocean. "For study purposes, we created what we call the 'Caribbean Box.' The Box includes an area where Columbus would most likely have been in 1492," Cerveny explains.

The ASU professor's computer model shows that no hurricanes have passed through the box during the last half of October in more than 100 years. "This is another remarkable statistic in Columbus' favor!" Cerveny adds. Although the admiral enjoyed favorable odds, the probability of coming across a hurricane was not zero. But would Columbus' fleet have survived if it did? Cerveny says "Yes," it would have. "After all, Columbus was a naturally gifted sailor. He used weather to the greatest advantage. He also was a skilled navigator."

Columbus did have a close call with bad weather during his fourth and final voyage in 1503. "Columbus saw clues that a major storm was brewing and predicted that it would hit Hispaniola," Cerveny says. "He didn't know the storm would be a hurricane because he had never seen one. But he recognized the signs of impending bad weather and warned the governor."

The governor ignored him and dispatched a fleet of 20 ships. The ships carried treasures of gold and jewels for the King of Spain. The valuable cargo never reached the Spanish crown. "That fleet went to the bottom of the Caribbean with all hands," Cerveny says.

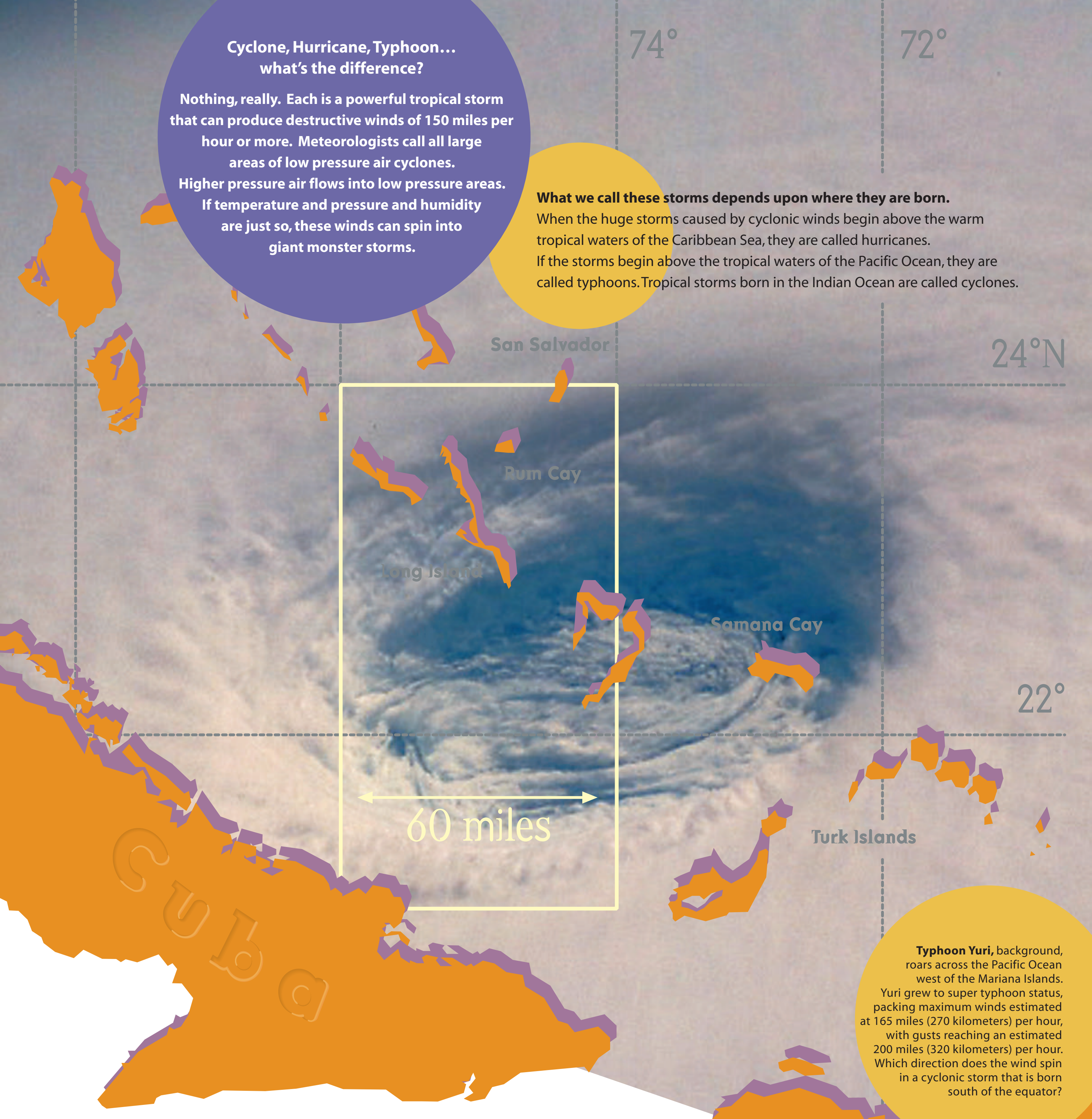
Columbus realized the danger and disobeyed the governor's orders. His ships stayed anchored safely in the harbor. The ships survived the powerful storm with only minor damage.

Historical records suggest that the 1490s were calm years in both the Old and New Worlds. Few major storms were recorded and harvests were good all across Europe. Other historical statistics reveal that climate

CrossLink

WEATHER AND HISTORY

Hold Onto Your Heads…
The fastest wind speed ever recorded was 231 miles per hour. This healthy little breeze took place at Mount Washington, New Hampshire on April 12, 1934.



Cyclone, Hurricane, Typhoon… what's the difference?

Nothing, really. Each is a powerful tropical storm that can produce destructive winds of 150 miles per hour or more. Meteorologists call all large areas of low pressure air cyclones. Higher pressure air flows into low pressure areas. If temperature and pressure and humidity are just so, these winds can spin into giant monster storms.

What we call these storms depends upon where they are born. When the huge storms caused by cyclonic winds begin above the warm tropical waters of the Caribbean Sea, they are called hurricanes. If the storms begin above the tropical waters of the Pacific Ocean, they are called typhoons. Tropical storms born in the Indian Ocean are called cyclones.

Typhoon Yuri, background, roars across the Pacific Ocean west of the Mariana Islands. Yuri grew to super typhoon status, packing maximum winds estimated at 165 miles (270 kilometers) per hour, with gusts reaching an estimated 200 miles (320 kilometers) per hour. Which direction does the wind spin in a cyclonic storm that is born south of the equator?

conditions worsened dramatically during the early 1500s. "Suddenly, there are many reports of severe storms and hurricanes, particularly from 1530 through the 1550s. Lots of Spanish ships were destroyed," Cerveny adds. "So, perhaps Christopher Columbus was lucky that he sailed to the New World a half century before this stormy period began."

If a hurricane had come across Columbus' path, America's history might have been very different.

fREakY WeATHeR...

Find the interactive extreme weather map at: **wmo.asu.edu/maps/map.html**

naKED CHICKENs ANd fALLiNG FiSH

BY DIANE BOUDREAU

It started out as a normal morning for A. D. Bajkov. He was eating breakfast with his wife in a restaurant in the small town of Marksville, Louisiana. Suddenly, a waitress hollered, "Quick, look! Fish are falling from the sky!" Bajkov, a wildlife biologist, ran outside to observe the strange event. The waitress was right—it was raining fishes.

This event happened in 1949. But it wasn't the first rain of fishes ever seen. People reported fish falling from the sky in India in 1830, Texas in 1886, Australia in 1906, and South Africa in 1909. The 1949 event was simply the first time a fishfall had ever been observed and recorded by a scientist.

Randy Cerveny loves weird weather stories. Over the past six years, he has collected more than 8,000 strange weather tales. Those tales include wacky stuff such as hailstones shaped like crosses. Or how about lightning strikes that cause your sweat to blow the clothes right off you. Even stranger: snow that turns blood-red when stepped on.

Cerveny is a climatologist at Arizona State University. He studies and teaches about weather and climate. He wrote a book describing some of the most interesting weather stories in his collection. The book is called *Freaks of the Storm*. "The title is a phrase that was used in the early part of the last century to describe strange phenomena that occurred during storms," Cerveny explains. "For example, when chickens would lose their feathers in a tornado, that would be called a freak of the storm."

Sometimes, the stories of how people try to figure out freaks of the storm are as interesting as the freaks themselves. For instance, tornadoes sometimes leave chickens completely plucked of their feathers, but otherwise healthy. People wanted to know how this happened. "At first people thought it was caused by wind speed. A scientist actually constructed a special gun and put a dead chicken in it and fired the gun to see if the force stripped it of its feathers," says Cerveny.

Mirage
In a hot arid desert, travelers often see what appears to be a shimmering lake in the distance. However, when they arrive at that location, there is only hot sand. The appearance of water was a mirage. A mirage is an optical effect produced by hot air rising from the ground during convection. Hot air acts like a lens that bends light in strange ways when hot and cold air are mixed.

wAteRSpOut

The gun did strip the chicken, but scientists today do not believe wind speed is responsible for tornado pluckings. “Now we think chickens actually are doing something called ‘panic molt.’ This is common in flightless birds,” Cerveny says. “When they are scared, they lose their feathers. If a predator is attacking and grabs them by the feathers, the feathers simply come out and the chicken escapes.”

Not all freaks of the storm involve animals. In the mid-1800s, people in Swan’s Quarter, N.C. decided to build a church. The congregation wanted to construct the church in the center of town, but the landowner wouldn’t sell the land. Instead, the church was built on the edge of town.

Later, a hurricane flooded the city. Many buildings were destroyed, but the church wasn’t harmed. Instead, it floated away! It floated down the street, turned a corner, and finally came to rest right on the plot of land where the congregation first wanted to build. “The owner decided that someone was sending him a message, and he sold the land to the church,” Cerveny says. The church is still there today.

And what about those falling fish? Where did they come from? Scientists aren’t completely sure. The most likely explanation is that the fish are picked up by waterspouts. Waterspouts are basically tornadoes that happen over water. The storm picks up the fish and drops them over land, often miles away. However, no one can explain why people only see fish falling. Why wouldn’t the waterspouts pick up plants, shells, and other water creatures and drop them over the land, too?

Science is all about answering questions. But one answer often leads to lots more questions. That’s what makes it fun. There is always more work to do.

Hot news, cold facts

Fried Eggs on the Sidewalk?
The highest temperature ever recorded in Arizona was 128 degrees Fahrenheit. The scorcher occurred in Lake Havasu City on June 29, 1994.

The highest temperature ever reached in the United States was 134 degrees Fahrenheit. This hellish high was recorded on July 10, 1913 in Death Valley, California.

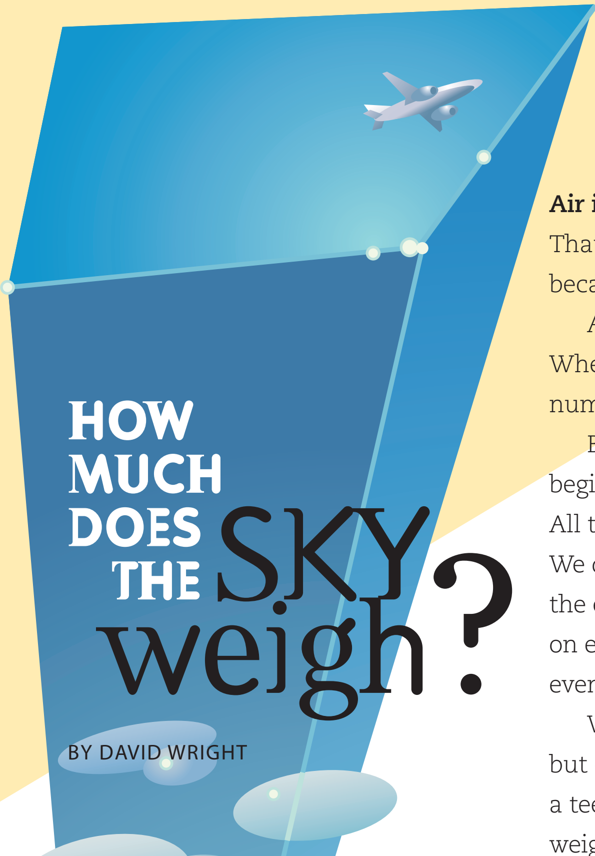
In the same year (1913), Phoenix reached its all-time lowest temperature of 16 degrees Fahrenheit on Jan. 7.

Hawley Lake in the White Mountains holds the record for the lowest temperature ever recorded in Arizona—a bone-numbing minus–40 degrees Fahrenheit on Jan. 7, 1971.

Quick-change
On January 22, 1943, the citizens of Spearfish, South Dakota got a big surprise. The temperature leaped from minus 4 degrees to 45 degrees Fahrenheit in only two minutes!

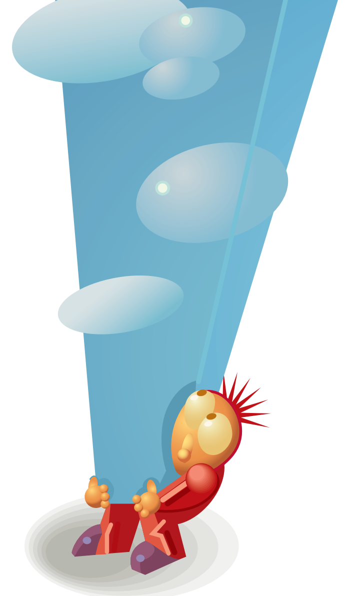
Sun tan lotion and parka please!
The Sahara Desert of North Africa can reach temperatures of more than 136 degrees Fahrenheit. Before you toss away your jackets, remember that the temperature has also gone down as low as 5 degrees in the mountains during the winter.

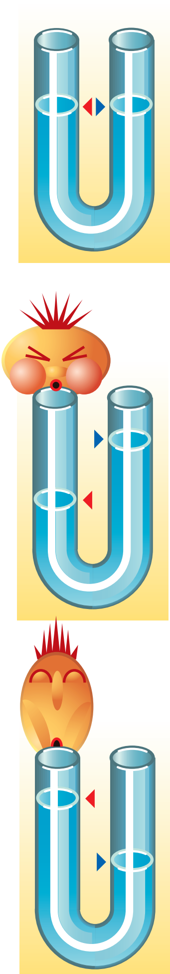
fiSH

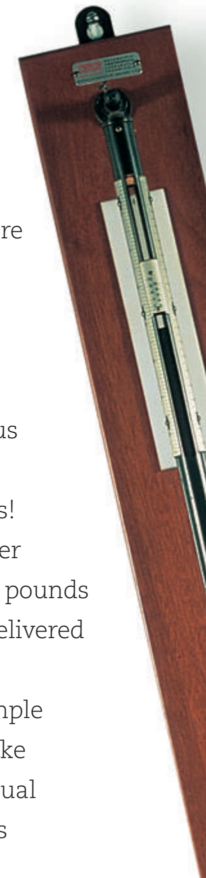


HOW MUCH DOES THE SKY weigh?

BY DAVID WRIGHT







Air is all around you. It presses against your body all the time. That's why we call it air pressure. Usually, you don't notice air pressure because it presses against you evenly in all directions.

Anyone can measure air pressure using a tool called a barometer. When we use a barometer to measure the air pressure, the resulting number is called the barometric pressure.

Barometers work because air has weight. The air that surrounds us begins at the surface of the Earth and goes up to the top of the sky. All that air, the entire atmosphere, weighs about 5 million billion tons! We don't get crushed because all that weight is distributed evenly over the entire surface of the Earth. The average force you feel is about 15 pounds on every square inch of your body. Because air is fluid, that force is delivered evenly over your entire body, not just on the top of your head.

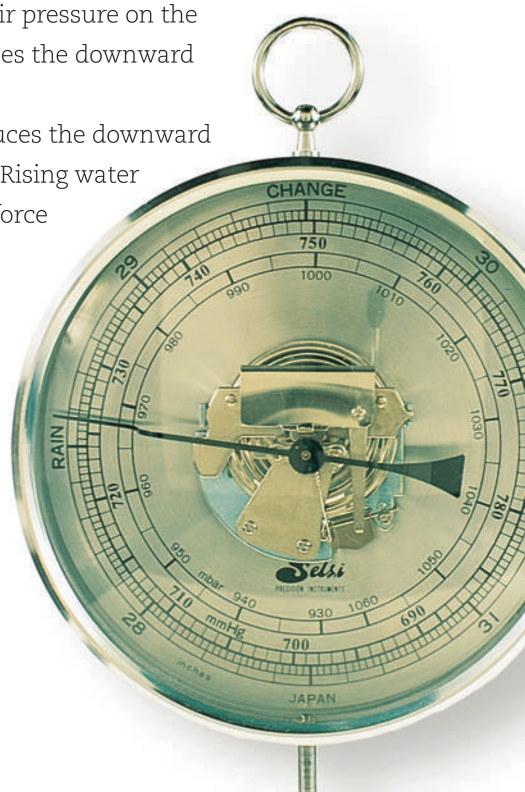
We can measure how much the air presses down on us with a simple but clever device. It's called a U-tube barometer and it works much like a teeter-totter. A teeter-totter can stay balanced as long as there is equal weight on both sides. If the weights are different, the teeter-totter tips to favor the heavy side. The same is true for a U-tube barometer.

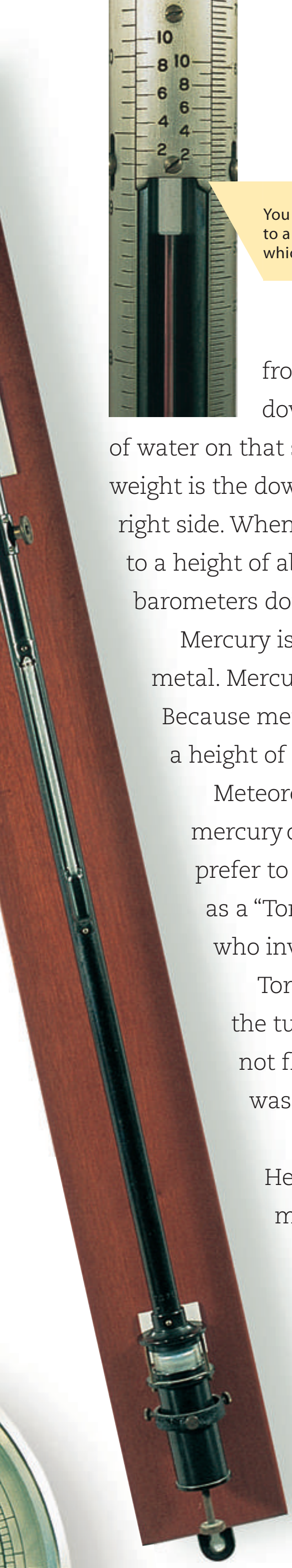
Look at the tube at left. It contains some water. With both ends open to the air, the water levels in each side are the same. This is because the air pressure over each side is the same. The water is balanced between the downward forces on each side, just like a teeter-totter.

Blow some air into the left side. The water levels change because you have made the air press down more than the air on the right side. In other words, you have increased the air pressure on the left side. The water moves until it balances the downward forces on both sides.

The loss of water on the left side reduces the downward force from water weight on the left side. Rising water on the right side adds to the downward force from water weight on the right side. This balances the force from the air pressure you added on the left side.

On the other hand, when you suck air from the left side, the water levels change in a different way. By removing air from the left side, you have made the air press down less than the air on the right side. Again, the water moves until it balances the downward forces on both sides.





You read air pressure from a U-tube barometer by comparing the column of mercury to a built-in ruler. The sliding plate is a special measuring device called a vernier which allows very precise readings.

If you use a strong vacuum pump to remove all the air from the left side, the air pressure there will be zero. The only downward force on the left side would be from a tall column of water on that side. The force on the other side that balances all that water weight is the downward force from the normal air pressure on the right side. When this is done, the water level on the left side rises to a height of about 34 feet. This is not very practical, so U-tube barometers don't actually use water as the liquid.

Mercury is used instead, because it is a very dense liquid metal. Mercury is about 14 times more dense than water. Because mercury is so heavy, normal air pressure pushes it to a height of only about 30 inches, or 760 millimeters.

Meteorologists measure air pressure by counting the inches of mercury on a barometer. Other scientists who work with gas pressures prefer to use millimeters. One millimeter of mercury is known as a "Torr." The Torr unit is named in honor of Evangelista Torricelli, who invented the mercury barometer in 1643.

Torricelli filled a long glass tube with mercury and inverted the tube into a dish. He observed that some of the mercury did not flow out and that the space above the mercury in the tube was a vacuum.

Torricelli was the first person to create and sustain a vacuum. He concluded that the day to day changes in the height of the mercury were caused by changes in the atmospheric pressure.

At sea level, the barometric pressure is high because sea level is the lowest place you can go. More air above you creates more pressure. In the high mountains or in an airplane, the barometric pressure is less. Because you are higher in the atmosphere, there is less air on top of you, so the pressure it creates is less.

In any given location, when the barometric pressure drops, you can expect a storm. When it increases, you can expect sunny weather.

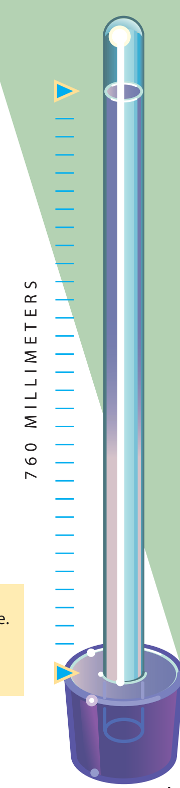
Aneroid barometers like this don't use liquid mercury to measure air pressure. Instead, they contain a small metal capsule. Air is pumped out of the capsule and it is sealed. A sensitive metal linkage is attached to the capsule. The capsule swells or shrinks as atmospheric pressure changes, and the movement is multiplied by the linkage to turn the pointer.

Pressure power

Pressure differences across the Earth's atmosphere drive large scale flows of wind. The wind can do useful work. People usually think of sailing ships and windmills as sucessful ways to capture the wind, but there are others.

Randall Cerveny holds a 1/8-scale model of a "wind wagon" that was made in 1860. A miller named Samuel Peppard built the wagon so he could go strike it rich in the Colorado gold rush. Peppard sailed his contraption from Kansas City almost all the way to Denver. About 50 miles out of Denver, a dust devil knocked over the wagon and destroyed it.

Cerveny, an ASU professor of climatology, is building a replica of the wagon with his students. They will try to sail it from Kansas City to Denver in 2010. "This is not going to be a pleasant ride. Back in the 1860s they didn't have shock absorbers!" says Cerveny. Still, the team is having a blast figuring out how to recreate the vehicle. "It's one of the first examples of an alternative energy mode of transportation. The students say this project is similar to a MythBusters type of thing," says Cerveny.



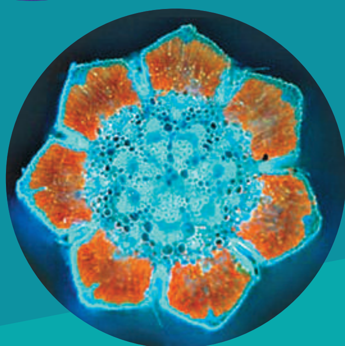
In any given location, when the barometric pressure drops, you can expect a storm. When it increases, you can expect sunny weather.

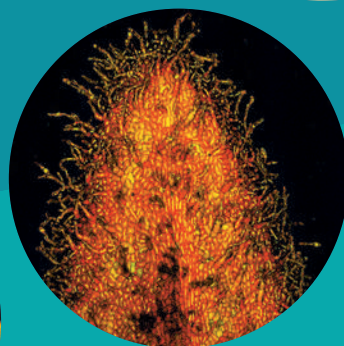
http://chainreaction.asu.edu

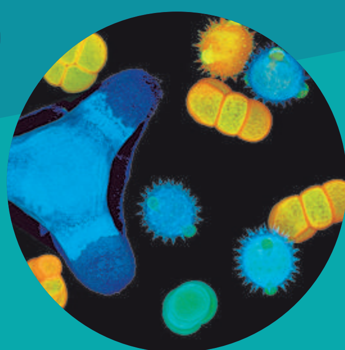
Ask a Biologist

http://askabiologist.asu.edu

Ask a Biologist is
an outreach program of
the Arizona State University
School of Life Sciences







Science is about curiosity. Science is about asking questions.

One answer often leads to a brand new set of questions. That is how science works. That is what learning is all about. Just think how great it would be if you could ask a real scientist for help with a tough question. Now you can. You can also hear the scientists themselves via podcasts from the site. Don't have a question? No problem. The site features backyard experiments you can do at home, coloring pages for young students, quizzes, and a new comic book science mystery with Dr. Biology. Check it all out at: http://askabiologist.asu.edu

Other resources at ASU:

ASU Mars Education Program
Make your own discoveries in space science.
http://marsed.asu.edu

Ecology Explorers
Work side by side with ASU scientists
and investigate your schoolyard.
http://caplter.asu.edu/explorers

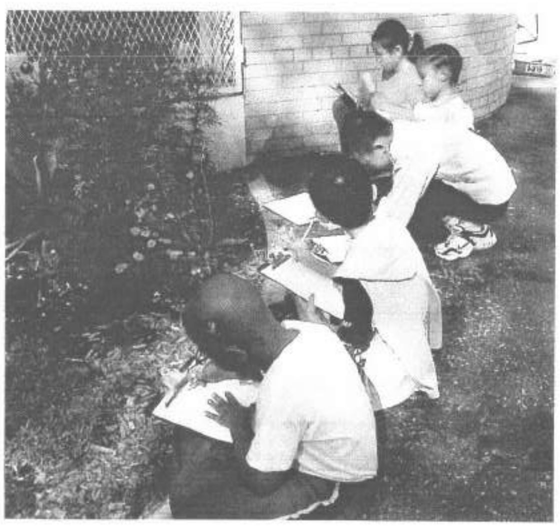
ASU in the Community
From photos of Mars to Sun Devil screensavers
to tips for living green, Club ASU is your
passport to everything cool online at ASU.
http://community.uui.asu.edu/

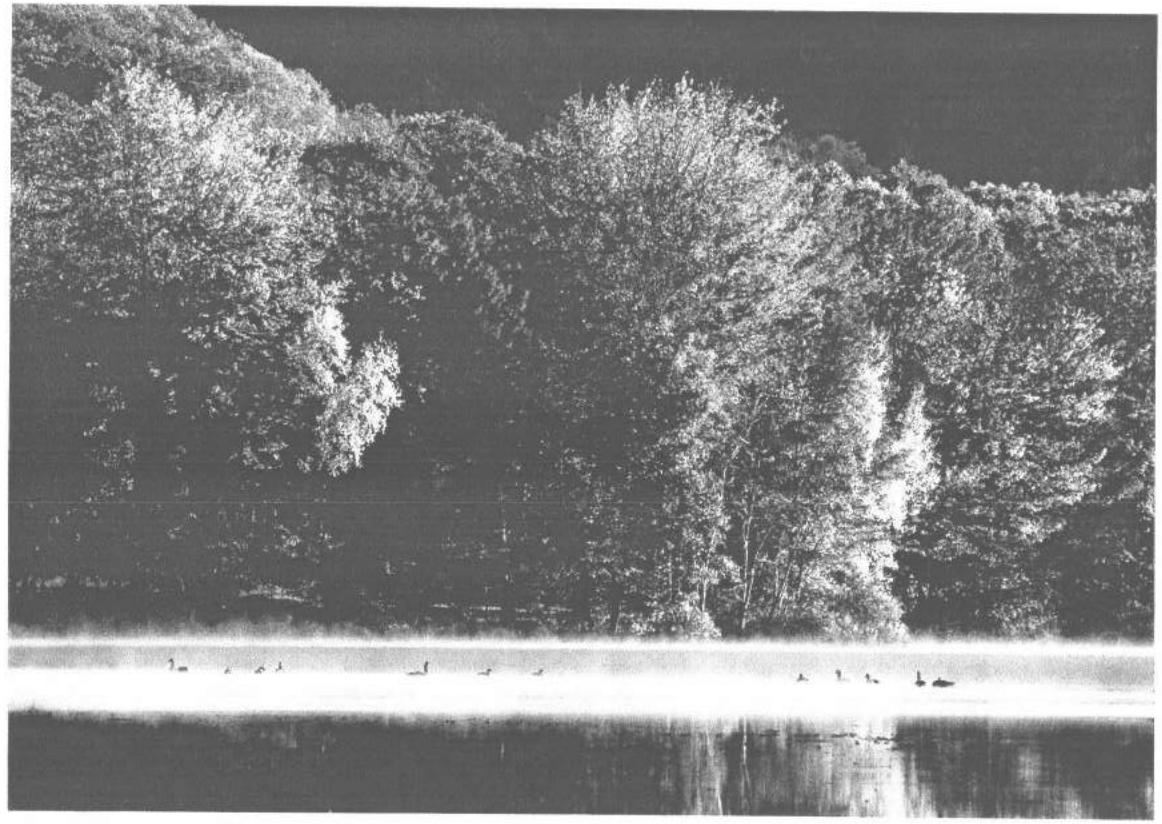
Inspired by Students 100 Years Ago, Today's Students Record the Seasons

Over a hundred years ago, students in Nova Scotia, Canada collected data that can provide clues to scientists—and citizen scientists—today. From 1900 to 1923, the school superintendent there, Dr. Alexander MacKay, set up a program for observing nature in schools all around the province. Students and teachers recorded the first arrival of various bird species such as cedar waxwings and ruby-throated hummingbirds. They recorded the first fruiting of various trees, days when fields were ready to be hayed and the sheep shorn, the first autumn frost, the first appearance of snakes and of frogs calling, and the first thawing of the ice on rivers and lakes. Over 1,400 different schools participated in collecting this data, which MacKay recorded in large notebooks. They surely had no idea how valuable it could be to students and scientists in the future.

Now, a century later, the *Thousand Eyes Project* has posted MacKay's data on the internet. They are reviving his dream of having students follow seasonal changes to find out what is happening in nature. Students are again recording what birds they see and the first day they see buds on trees and blooms of flowers. With a thousand eyes observing natural events—the clues of seasonal change—scientists and citizen scientists can compare the data from 100 years ago with data collected today, and see nature's response to Nova Scotia's changing climate.

The study of how nature changes with the seasons is called *phenology*. The term comes from a Greek word meaning "to appear." Like the Canadian students one hundred years ago and today, many children are now helping scientists by collecting phenological data. You, too, can be a citizen scientist and observe changes in nature. But how can you get this information to scientists who may be able to use it? There are many programs to help you connect with scientists, and more are being created all the time. Keep reading to see how you, too, can be a citizen scientist.





Previous Page: Many birds are changing their ranges in response to climate change. The Baltimore oriole, the state bird of Maryland, is living farther north than before and in the near future it may migrate to the north and not be found spending summers in Maryland any more.

Above: Fall in the northeastern part of North America is marked by the maples and oaks turning color. It is a regular event of the seasons that is happening later, while at the same time some of the maples are moving north following the warmer climate.

Top left: These students are recording when the first buds appear on various plants in their neighborhood as part of *Project Budburst*.

Bottom left: These students are in their schoolyard closely observing seasonal changes in plants.

Weather vs. Climate: What's the Difference?

People often talk about climate and weather as the same thing. However, they are quite different and these differences have important implications for how we predict changes in weather and climate.

Weather

Weather describes the atmospheric conditions at a specific place at a specific point in time. For example, the observed weather in Seattle, Washington, on Saturday, October 16, 2010 was sunny with a high of 57°F.

Weather is generally described in short time frames - minutes, hours, days, and weeks. Conditions associated with weather include (but are not limited to) sunshine, rain, cloud cover, winds, hail, snow, sleet, freezing rain, flooding, blizzards, ice storms, and thunderstorms (NASA 2010).

Climate

Climate refers to the statistics of weather. In other words, the average pattern for weather over a period of months, years, decades, or longer in a specific place. Going back to our earlier example from the weather discussion, the *average* high temperature for Seattle, Washington, on October 16 for 1971-2000 is 60°F. This value is determined by taking the average of all high temperatures recorded for the 30 October 16ths that have occurred between 1971-2000.

These examples of actual versus average conditions point to an important difference between weather and climate: while climate is what you expect, weather is what you get. Another easy way to remember the difference between weather and climate is the following statement:

"You pick your vacation destination based on the climate but pack your suitcase based on the weather."

Climate can vary seasonally or annually (e.g., because of El Niño or La Niña), over decades (e.g., because of the Pacific Decadal Oscillation), or over much long time scales (centuries or more). Climate has always varied because of natural causes. Increasingly, however, human increases in greenhouse gas emissions are beginning to cause changes in climate as well.

The following table summarizes some of the important differences between weather and climate.

	Weather	Climate
Definition	Describes the atmospheric conditions at a specific place at a specific point in time.	Describes the average conditions expected at a specific place at a given time.
Time frame	Short term: Minutes, hours, days, or weeks	Long term: Months, years, decades, or longer
Determined by:	Real-time measurements of atmospheric pressure, temperature, wind speed and direction, humidity, precipitation, could cover, and other variables	Aggregating weather statistics over periods of 30 years ("climate normals").
Study	Meteorology	Climatology
Table sources/modified from: NASA 2010, diffen.com		

http://cses.washington.edu/cig/pnwc/weathervsclimate.shtml

Weather is the day-to-day state of the atmosphere in a region, and its short-term (minutes to weeks) variation whereas

Climate is defined as statistical weather information that describes the variation of weather at a given place for a specified interval. They are both used interchangeably sometimes but differ in their measure of time, and trends that affect them.

Weather is the combination of temperature, humidity, precipitation, cloudiness, visibility, and wind. In popular usage, climate represents the synthesis of weather; more formally it is the weather of a locality averaged over some period (usually 30 years) plus statistics of weather extremes.

In a 2012 survey, a majority of Americans blamed global warming (or "climate change") for erratic weather patterns in the country, especially heat waves.

Comparison chart

	Climate	Weather
Definition	Describes the average conditions expected at a specific place at a given time. A region's climate is generated by the climate system, which has five components: atmosphere, hydrosphere, cryosphere, land surface, and biosphere.	Describes the atmospheric conditions at a specific place at a specific point in time. Weather generally refers to day-to-day temperature and precipitation activity
Components	Climate may include precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, and hail storms over a long period of time.	Weather includes sunshine, rain, cloud cover, winds, hail, snow, sleet, freezing rain, flooding, blizzards, ice storms, thunderstorms, steady rains from a cold front or warm front, excessive heat, heat waves and more
Forecast	By aggregates of weather statistics over periods of 30 years	By collecting meteorological data, like air temperature, pressure, humidity, solar radiation, wind speeds and direction etc.
Determining factors	Aggregating weather statistics over periods of 30 years ("climate normals").	Real-time measurements of atmospheric pressure, temperature, wind speed and direction, humidity, precipitation, cloud cover, and other variables
About	Climate is defined as statistical weather	Weather is the day-to-day state of the

	Climate	Weather
	information that describes the variation of weather at a given place for a specified interval.	atmosphere, and its short-term (minutes to weeks) variation
Time period	Measured over a long period	Measured for short term
Study	Climatology	Meteorology

http://www.diffen.com/difference/Climate_vs_Weather

What's the Difference Between Weather and Climate?
02.01.05

The difference between weather and climate is a measure of time. Weather is what conditions of the atmosphere are over a short period of time, and climate is how the atmosphere "behaves" over relatively long periods of time.

In addition to long-term climate change, there are shorter term climate variations. This so-called climate variability can be represented by periodic or intermittent changes related to El Niño, La Niña, volcanic eruptions, or other changes in the Earth system.

What Weather Means
Weather is basically the way the atmosphere is behaving, mainly with respect to its effects upon life and human activities. The difference between weather and climate is that weather consists of the short-term (minutes to months) changes in the atmosphere. Most people think of weather in terms of temperature, humidity, precipitation, cloudiness, brightness, visibility, wind, and atmospheric pressure, as in high and low pressure.

In most places, weather can change from minute-to-minute, hour-to-hour, day-to-day, and season-to-season. Climate, however, is the average of weather over time and space. An easy way to remember the difference is that climate is what you expect, like a very hot summer, and weather is what you get, like a hot day with pop-up thunderstorms.

Things That Make Up Our Weather
There are really a lot of components to weather. Weather includes sunshine, rain, cloud cover, winds, hail, snow, sleet, freezing rain, flooding, blizzards, ice storms, thunderstorms, steady rains from a cold front or warm front, excessive heat, heat waves and more.

In order to help people be prepared to face all of these, the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS), the lead forecasting outlet for the nation's weather, has over 25 different types of warnings, statements or watches that they issue. Some of the reports NWS issues are: Flash Flood Watches and Warnings, Severe Thunderstorm Watches and Warnings, Blizzard Warnings, Snow Advisories, Winter Storm Watches and Warnings, Dense Fog Advisory, Fire Weather Watch, Tornado Watches and Warnings, Hurricane Watches and Warnings. They also provide Special Weather Statements and Short and Long Term Forecasts.

NWS also issues a lot of notices concerning marine weather for boaters and others who dwell or are staying near shorelines. They include: Coastal Flood Watches and Warnings, Flood Watches and Warnings, High Wind Warnings, Wind Advisories, Gale Warnings, High Surf Advisories, Heavy Freezing Spray Warnings, Small Craft Advisories, Marine Weather Statements, Freezing Fog Advisories, Coastal Flood Watches, Flood Statements, Coastal Flood Statement.

Who is the National Weather Service?
According to their mission statement, "The National Weather Service provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy. NWS data and products form a national information database and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community."

To do their job, the NWS uses radar on the ground and images from orbiting satellites with a continual eye on Earth. They use reports from a large national network of weather reporting stations, and they launch balloons in the air to measure air temperature, air pressure, wind, and humidity. They put all this data into various computer models to give them weather forecasts. NWS also broadcasts all of their weather reports on special NOAA weather radio, and posts them immediately on their Interactive Weather Information Network website at: http://iwin.nws.noaa.gov/iwin/graphicsversion/bigmain.html.

What Climate Means
In short, climate is the description of the long-term pattern of weather in a particular area.

Some scientists define climate as the average weather for a particular region and time period, usually taken over 30-years. It's really an average pattern of weather for a particular region.

When scientists talk about climate, they're looking at averages of precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, and hail storms, and other measures of the weather that occur over a long period in a particular place.

For example, after looking at rain gauge data, lake and reservoir levels, and satellite data, scientists can tell if during a summer, an area was drier than average. If it continues to be drier than normal over the course of many summers, than it would likely indicate a change in the climate.

http://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html

We hear about weather and climate all of the time. Most of us check the local weather forecast to plan our days. And climate change is certainly a “hot” topic in the news. There is, however, still a lot of confusion over the difference between the two.

Think about it this way: Climate is what you expect, weather is what you get.

Weather is what you see outside on any particular day. So, for example, it may be 75 degrees and sunny or it could be 20 degrees with heavy snow. That’s the weather.

Climate is the average of that weather. For example, you can expect snow in the Northeast in January or for it to be hot and humid in the Southeast in July. This is climate. The climate record also includes extreme values such as record high temperatures or record amounts of rainfall. If you’ve ever heard your local weather person say “today we hit a record high for this day,” she is talking about climate records.

So when we are talking about climate change, we are talking about changes in *long-term* averages of daily weather. In most places, weather can change from minute-to-minute, hour-to-hour, day-to-day, and season-to-season. Climate, however, is the average of weather over time and space.

AZ Statewide: **National Weather Service (NWS) Automated Surface Observing Systems Arizona Stations**

The Automated Surface Observing Systems (ASOS) program is a joint effort of the National Weather Service (NWS), the Federal Aviation Administration (FAA), and the Department of Defense (DOD). ASOS serves as the Nation's primary surface weather observing network. ASOS is designed to support weather forecast activities and aviation operations and, at the same time, support the needs of the meteorological, hydrological, and climatological research communities. ASOS works non-stop, updating observations every minute, 24 hours a day, every day of the year observing basic weather elements, such as cloud cover, precipitation, wind, sea level pressure, and conditions, such as rain, snow, freezing rain, thunderstorms, and fog. There are 18 ASOS stations in Arizona.

National Weather Service (NWS) Cooperative Observer Program Arizona Sites

The National Weather Service (NWS) Cooperative Observer Program (COOP) is truly the Nation's weather and climate observing network of, by and for the people. More than 10,000 volunteers take observations on farms, in urban and suburban areas, National Parks, seashores, and mountaintops. The data are representative of where people live, work and play. The COOP was formally created in 1890 under the NWS Organic Act to provide observational meteorological data, usually consisting of daily maximum and minimum temperatures, snowfall, and 24-hour precipitation totals, required to define the climate of the United States and to help measure long-term climate changes, and to provide observational meteorological data in near real-time to support forecast, warning and other public service programs of the NWS.

The data are also used by other federal (including the Department of Homeland Security), state and local entities, as well as private companies (such as the energy and insurance industries). In some cases, the data are used to make billions of dollars worth of decisions. There are 170 COOP sites in Arizona.

http://oceanservice.noaa.gov/facts/weather_climate.html

http://www.legislative.noaa.gov/NIYS/

National Snow and Ice Data Center

What is the difference between weather and climate?

Weather is the day-to-day state of the atmosphere, and its short-term variation in minutes to weeks. People generally think of weather as the combination of temperature, humidity, precipitation, cloudiness, visibility, and wind. We talk about changes in weather in terms of the near future: "How hot is it right now?" "What will it be like today?" and "Will we get a snowstorm this week?"

Climate is the weather of a place averaged over a period of time, often 30 years. Climate information includes the statistical weather information that tells us about the normal weather, as well as the range of weather extremes for a location.

We talk about climate change in terms of years, decades, and centuries. Scientists study climate to look for trends or cycles of variability, such as the changes in wind patterns, ocean surface temperatures and precipitation over the equatorial Pacific that result in El Niño and La Niña, and also to place cycles or other phenomena into the bigger picture of possible longer term or more permanent climate changes.

Forecasting weather and predicting climate

Weather forecasters try to answer questions like: What will the temperature be tomorrow? Will it rain? How much rain will we have? Will there be thunderstorms? Today, most weather forecasts are based on models, which incorporate observations of air pressure, temperature, humidity and winds to produce the best estimate of current and future conditions in the atmosphere. A weather forecaster then looks at the model output to figure out the most likely scenario. The accuracy of weather forecasts depend on both the model and on the forecaster's skill. Short-term weather forecasts are accurate for up to a week. Long-term forecasts, for example seasonal forecasts, tend to use statistical relationships between large-scale climate signals such as El Niño and La Niña and precipitation and temperature to predict what the weather will be like in one to six months time.

Climate predictions take a much longer-term view. These predictions try to answer questions like how much warmer will the Earth be 50 to 100 years from now? How much more precipitation will there be? How much will sea level rise? Climate predictions are made using global climate models. Unlike weather forecast models, climate models cannot use observations because there are no observations in the future.

Arctic climate

Like other places on Earth, the weather in the Arctic varies from day to day, from month to month, and from place to place. But the Arctic is a unique place for weather and climate, because of the special factors that influence it. Sunlight is perhaps the most important of those factors. Above the Arctic Circle, the sun disappears in the winter, leaving the region dark and cold. What light does reach the region in the winter comes in at a low angle. In summers, the sun shines around the clock, bringing warmth and light. The Arctic also experiences frequent **inversions**. Inversions occur when cold air settles close to the ground, with warm air on top of it. Inversions separate the air into two layers, like oil and water: this tends to slow down the winds close to the surface. Over cities, inversions can trap pollutants, creating smoggy conditions that last until the inversion clears.

Scientists separate the Arctic into two major climate types. Near the ocean, a **maritime** climate prevails. In Alaska, Iceland, and northern Russia and Scandinavia, the winters are stormy and wet, with snow and rainfall reaching 60 cm (24 inches) to 125 cm (49 inches) each year. Summers in the coastal regions tend to be cool and cloudy; average temperatures hover around 10 degrees Celsius (50 degrees Fahrenheit).

Away from the coasts, the interior regions of the Arctic lands have a continental climate. The weather is dryer, with less snow in the winter and sunny summer days. Winter weather can be severe, with frigid temperatures well below freezing. In some regions of Siberia, average January temperatures are lower than -40 degrees Celsius (-40 degrees Fahrenheit). In the summer, the long days of sunshine thaw the top layer of **permafrost** and bring average temperatures above 10 degrees Celsius (50 degrees Fahrenheit). At some weather stations in the interior, summer temperatures are warmer than 30 degrees Celsius (86 degrees Fahrenheit).

http://nsidc.org/cryosphere/arctic-meteorology/climate_vs_weather.html

WHAT'S THE DIFFERENCE BETWEEN CLIMATE AND WEATHER?

Weather is what's happening in the atmosphere on any given day, in a specific place. Local or regional weather forecasts include temperature, humidity, winds, cloudiness, and prospects for storms or other changes over the next few days.

Climate is the average of these weather ingredients over many years. Some meteorologists like the saying that "climate is what you expect; weather is what you get," memorable words variously attributed to Mark Twain, Robert Heinlein, and others.

In practical terms, the climate for a particular city, state, or region tells you whether to pack short-sleeved shirts and shorts or parkas and mittens before you visit, while the local weather forecast tells you if you'll want to wear the parka by itself or with an extra sweater today.

WHAT'S A NORMAL CLIMATE?

Climate varies across space and time, so climate is studied on a variety of spatial and time scales.

To interpret today's atmospheric conditions, we need a reference period of average, or "normal," climate to compare it against. How long is long enough to define the average climate **for a city, state, or region**? The National Oceanic and Atmospheric Administration's National Weather Service calculates a **30-year average** once a decade. The current "normals" (issued July 1, 2011) are based on data from 1981 to 2010.

When it comes to **climate on a global scale**, the "normal" reference period depends on which climate components scientists want to study. For example, many scientists compare average global temperatures, precipitation, and other variables for the 20th and 21st centuries with the 30-year averages for 1870 to 1899, before major industrialization produced large quantities of greenhouse gas.

You can see how recent observations and future projections of warming and cooling compare to conditions at the end of the 19th century by watching a visualization of data from the NCAR-based Community Climate System Model in our Climate Change Multimedia Gallery.

BEFORE THERMOMETERS

To understand how climate varies across time, scientists examine three kinds of climate data: observations, historical accounts, and environmental evidence locked up in fossils, ice cores, and other "proxy climate records."

Observations of temperature at Earth's surface date back as far as 350 years for some locations in England, but only about 100 to 150 years in most of the developed world. But even before the thermometer was invented, **ancient civilizations kept records** of droughts, floods, unusual hot or cold weather, and other climate indicators, including planting and harvest times.

While human accounts can take us back hundreds or thousands of years, we need other tools to understand how Earth's climate has varied during its much longer lifetime of about 4.5 billion years.

Paleoclimatology delves into the deep history of past climate variation through what are called "proxy records." Air bubbles trapped in ice cores, the composition of lake sediments, changes in tree rings, pollen fossils, and other parts of Earth's ancient environment have given scientists many clues to past temperature, precipitation, wind patterns, and the chemical composition of the atmosphere through time.

Observations, historic accounts, and paleoclimate data are used to test the reliability of computer models that simulate Earth's climate on time scales from decades, to centuries, to millennia. Studying prehistoric variations can also provide important clues about what to expect in a warmer world.

https://www2.ucar.edu/climate/faq/whats-difference-between-climate-and-weather

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

Developed by The Arboretum at Flagstaff
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Phenology in Your Backyard: A Guide to Developing Your Own Phenology Garden

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 19^{th} 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.

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

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:	Other Evidence:
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	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)
- http://ltrr.arizona.edu/ (dendrochronology lab at the University of Arizona)
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- http://www.sega.nau.edu (Southwest Experimental Garden Array)
- https://www.usanpn.org/nn/species_search (National Phenology Network)

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

Books/media:

- *A Teacher's Guide to How We Know What We Know About Our Changing Climate*, p. 28-33
- *Integrating climate change and genetic research to restore western landscapes,* the Arboretum at Flagstaff
- *Climate Change is Happening*, The Arboretum at Flagstaff brochure

Photocopies:

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- *Natural Inquirer: Number 14 - Climate Change Edition*, p. 20-28
- Carbon Cycle Role-play Lesson Plan
- Carbon Cycle Role-play cards (printed front and back) – laminating will help preserve these for future use
- *Phenology in Your Backyard* Guide
- Albedo Effect Lesson Plan
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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. Engineers 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.

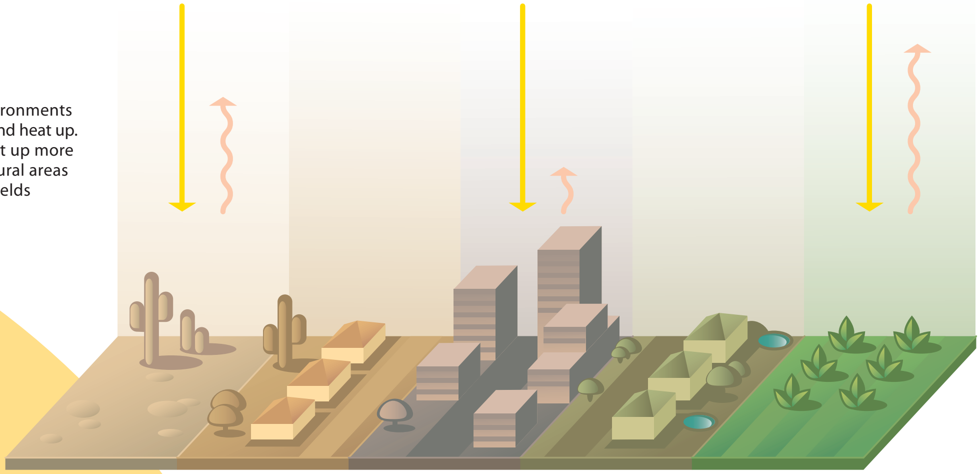
Agricultural areas are cooler than natural desert, Brazel says. This is because farms have a lot of water and plants. When water evaporates, it lowers the temperature of whatever is around it. For example, your body cools off when your sweat evaporates.

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.

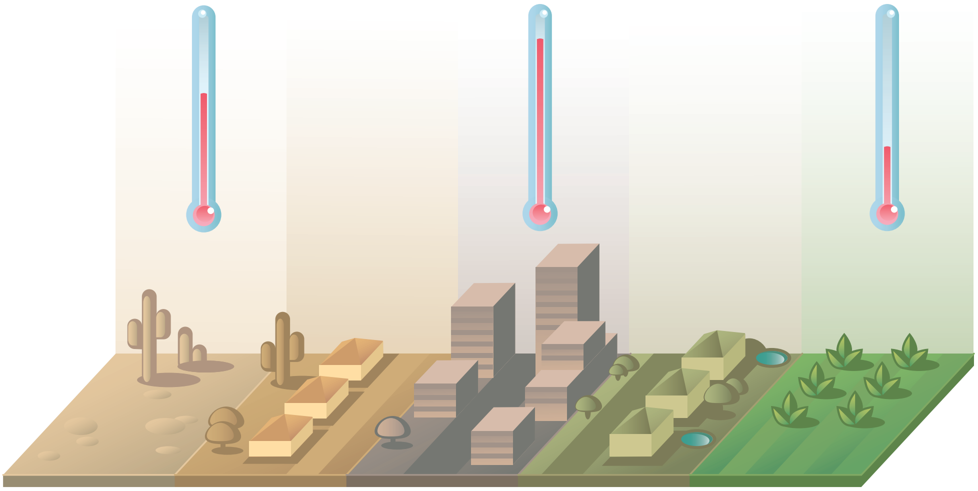
On the other end of the spectrum is vegetation—good old green plants. The sun's energy goes into evaporating the water that these plants receive, not into the ground. The researchers are finding out that neighborhoods with more plants and more water (such as swimming pools) are cooler than neighborhoods 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.

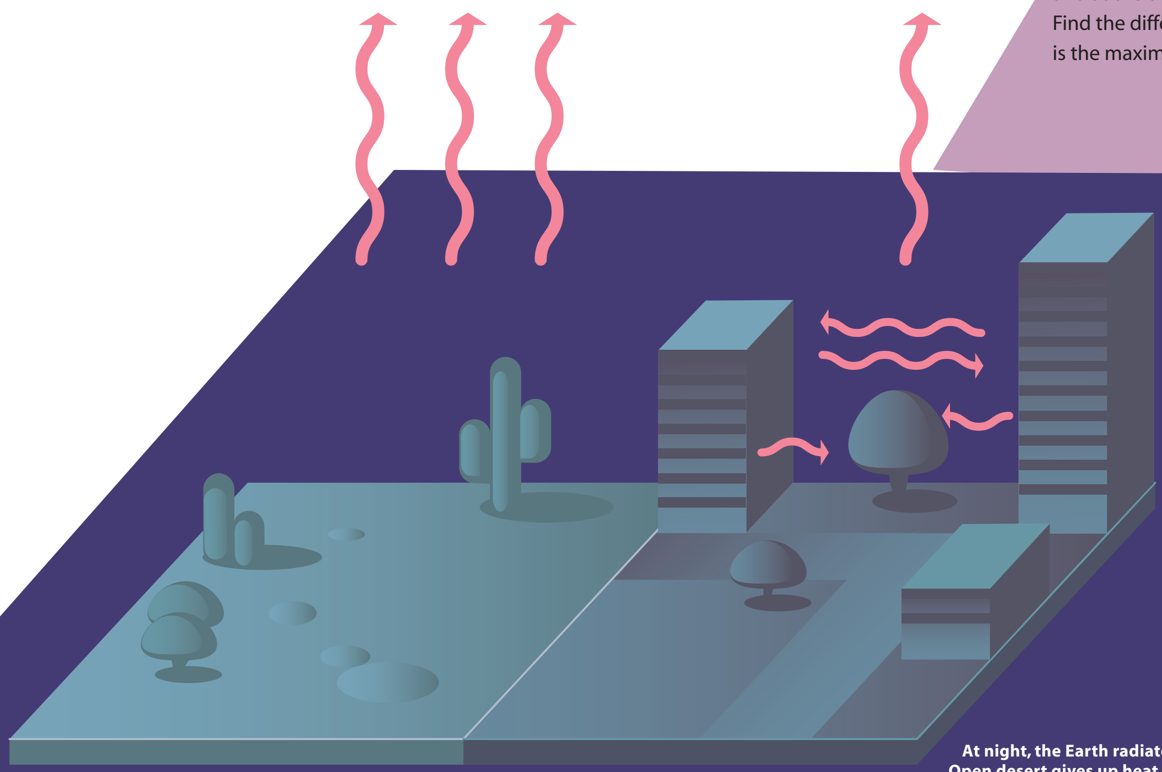
The way buildings are arranged can also have an effect on heat islands. Brazel talks about "urban canyons," created when you place tall buildings along narrow streets. The buildings provide shade and create cooling wind patterns. "The city of Phoenix was planned long ago," says Brazel. "It has wide streets 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.

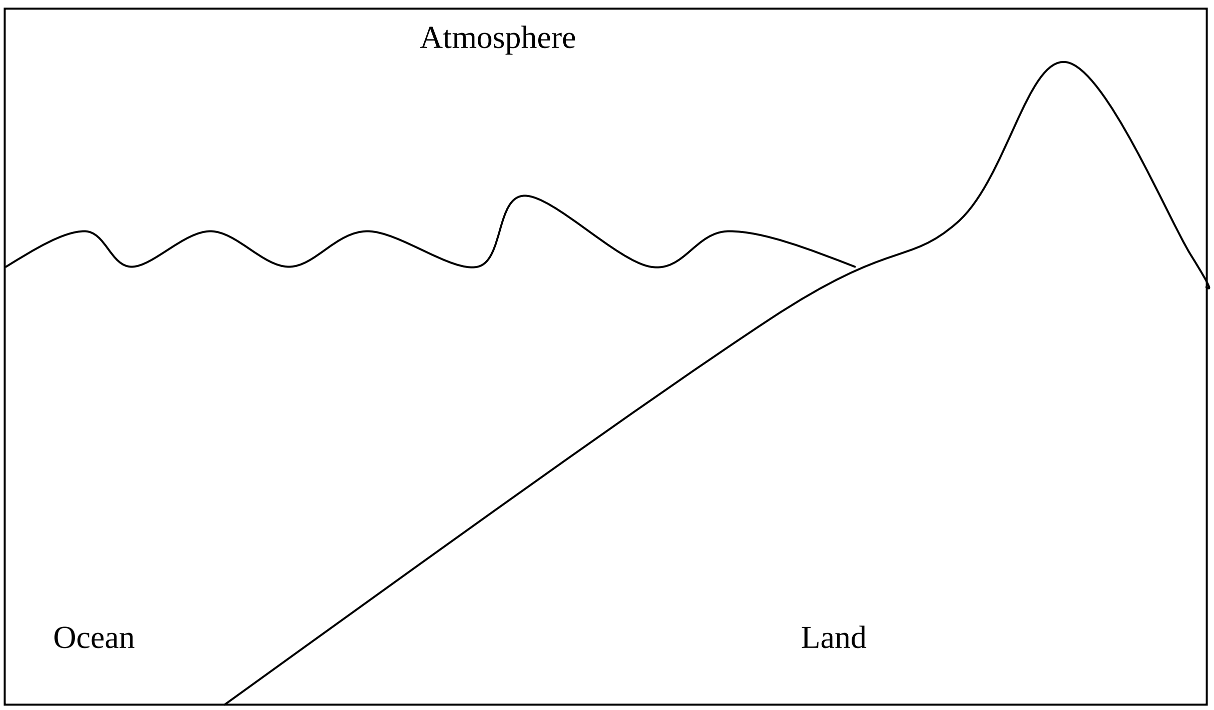
There are natural fluctuations in the carbon cycle, but humans have been changing the carbon flows on earth at an unnatural rate. The major human-induced changes result in increased carbon dioxide in the atmosphere. The largest source of this change is burning fossil fuels, but other actions such as 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.

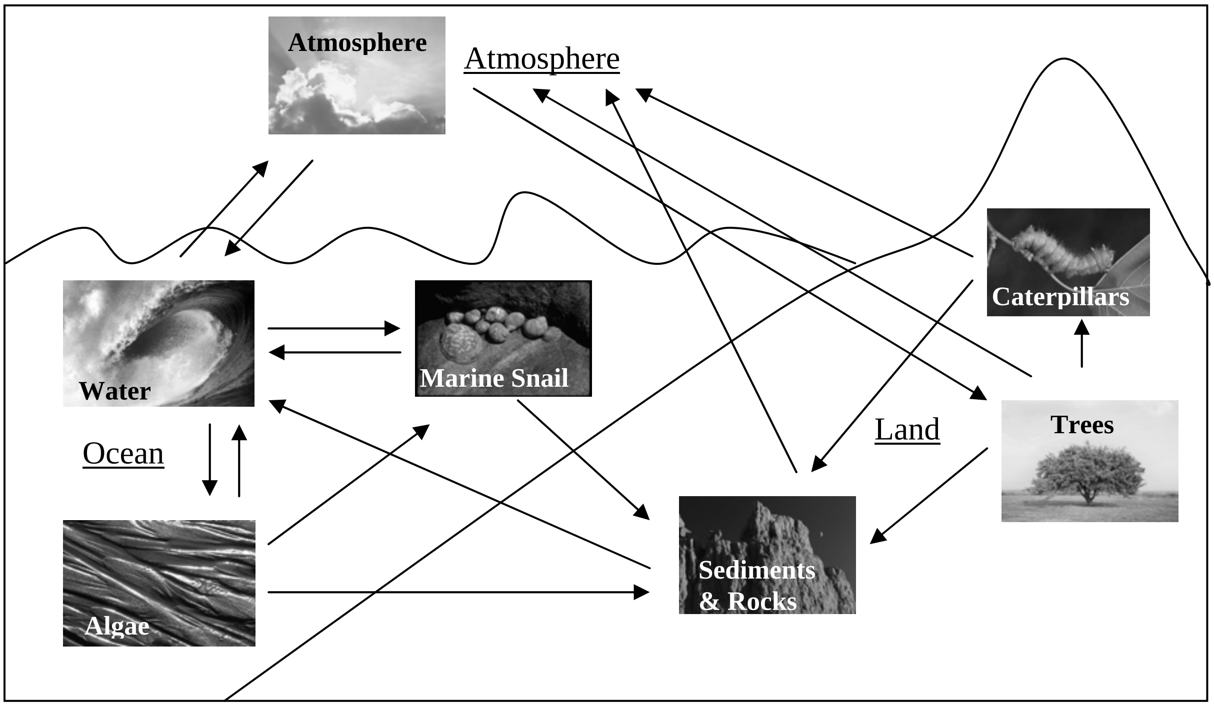
Procedure

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.

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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

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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.

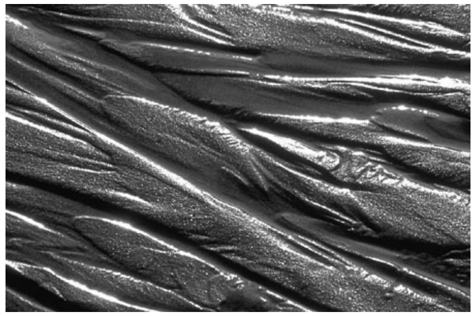
3. I am taking dissolved carbon dioxide and putting it back in the atmosphere as carbon dioxide gas.

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

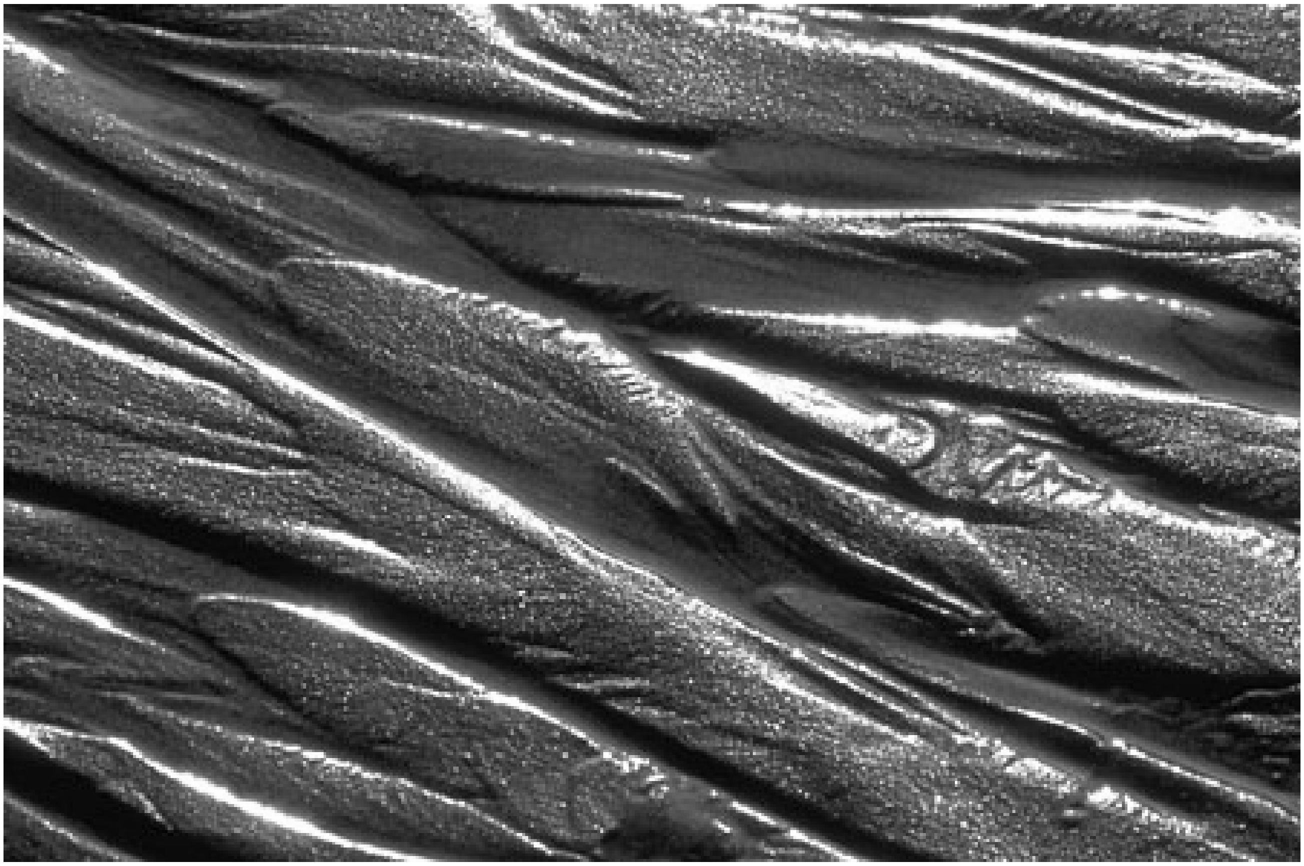
1. I am giving carbon to water when I die and decompose and when I perform respiration.

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



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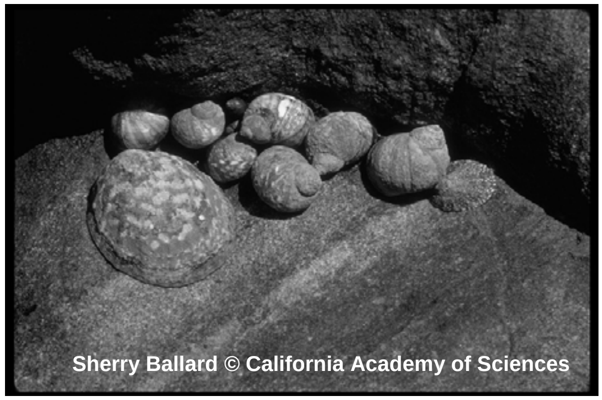
Carbon Cycle Role-Play Card

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

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

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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

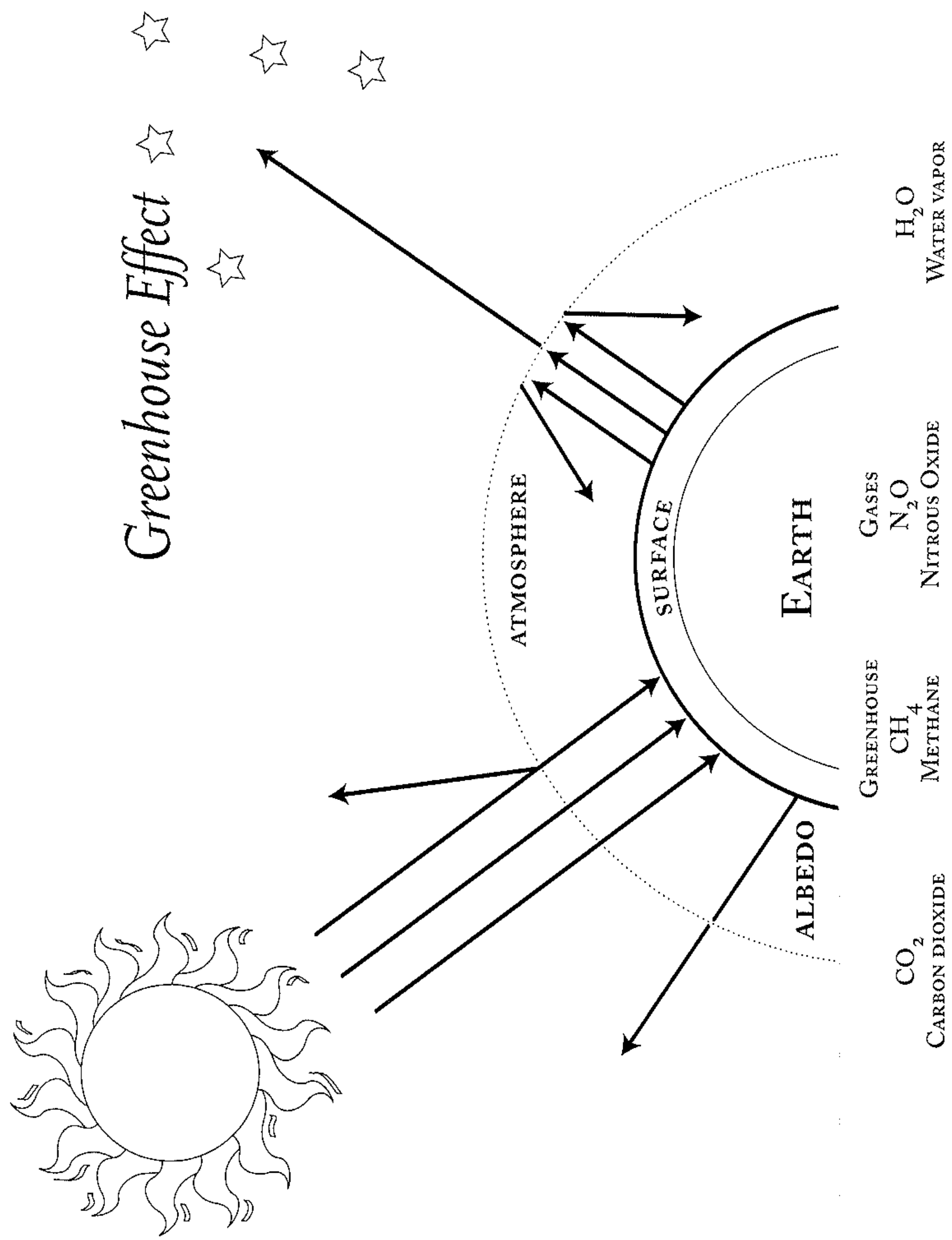
1. I am giving carbon to the atmosphere because when I respire I release carbon dioxide to the atmosphere.

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

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:

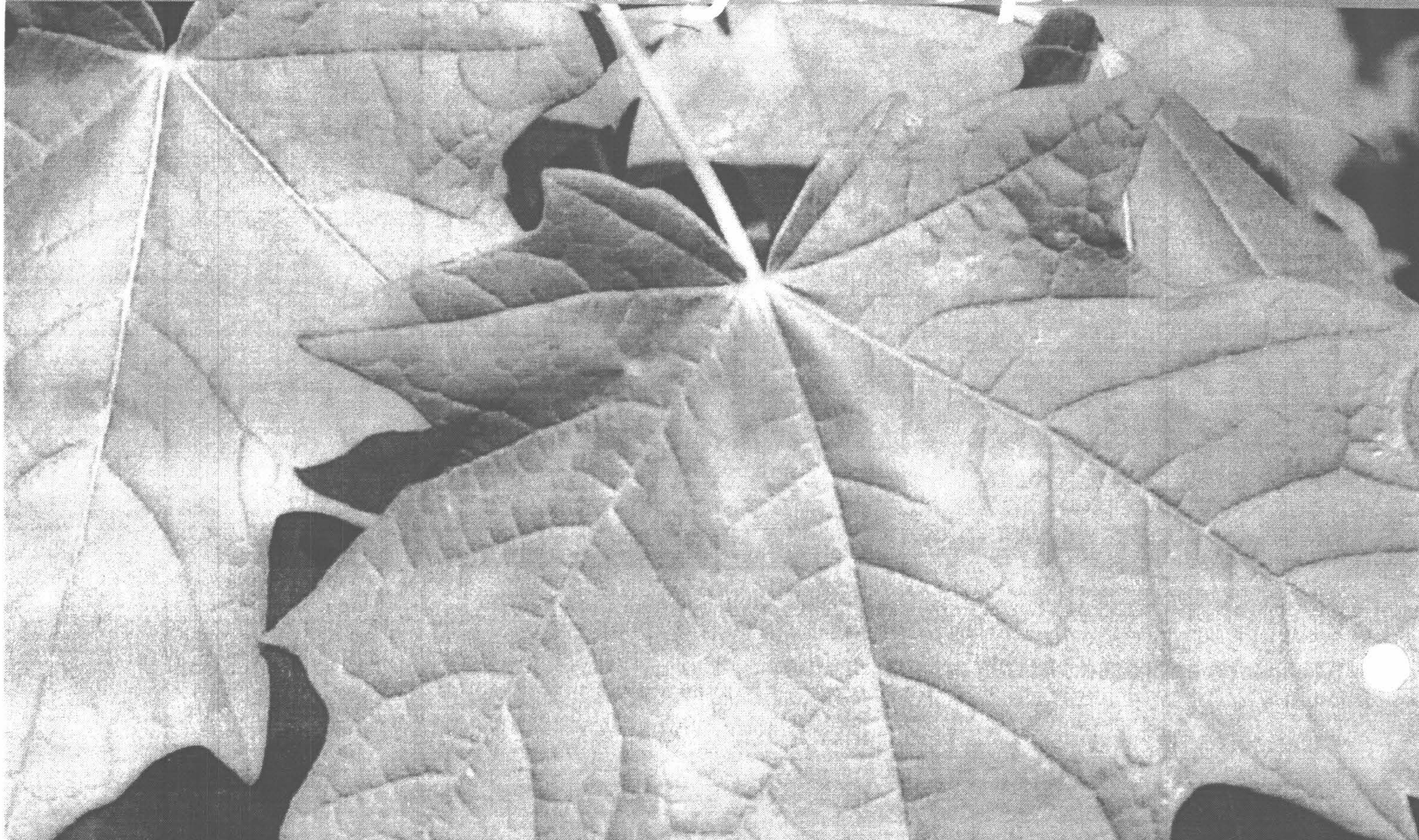
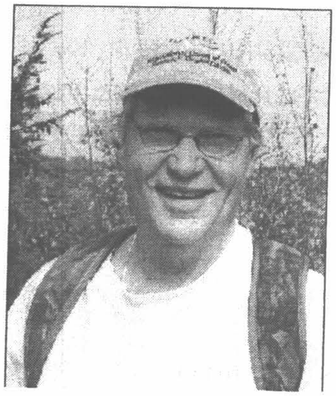


Photo courtesy of Paul Wray, Iowa State University, http://www.bugwood.org.

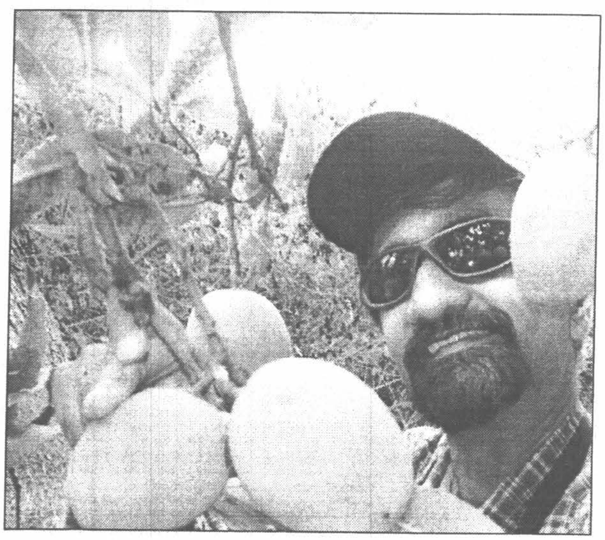
The Possible Impact of Climate Change on Forest Habitat

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. ▶

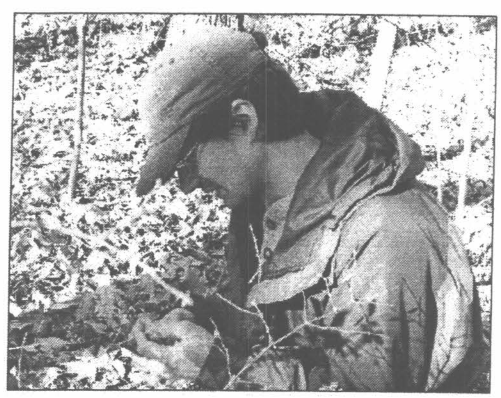


▼ **Mr. Anantha Prasad**, Landscape Ecologist: My favorite science experience is combining what I have learned and gaining insights. For example, I like to look at information about climate change, **topography,** where different plant and animal species are found, and the properties of soils in a particular 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** ləst): 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.

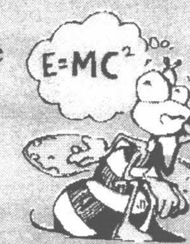
▼ **Dr. Stephen Matthews**, Wildlife Landscape Ecologist: My favorite science experience is coming up with new research questions based either on my current work or a new area of ecology. Then I like to go out and try to solve the problem in an attempt to advance my understanding of the natural world.



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.

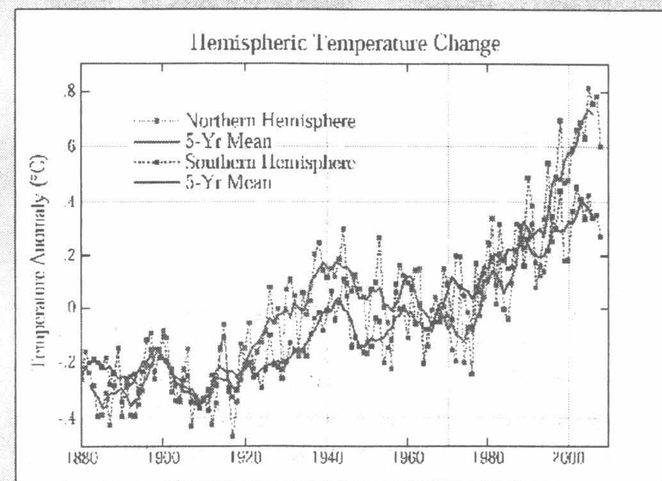


Figure 1. The trend in average yearly temperature since 1880. What trend do you see in this graph? (From http://data.giss.nasa.gov/gistemp/graphs/Fig.A3.pdf)

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.

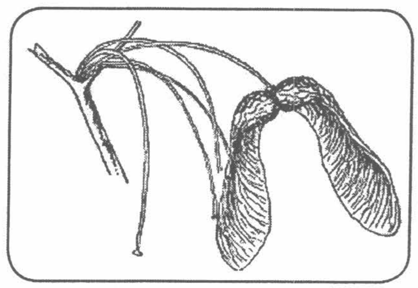
The scientists in this study were interested in trees that live in the Eastern United States (**figure 2**). They wanted to explore how the habitat of these trees might change in the future as the climate changes. They also wanted to know how different tree species might move in response to a changing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

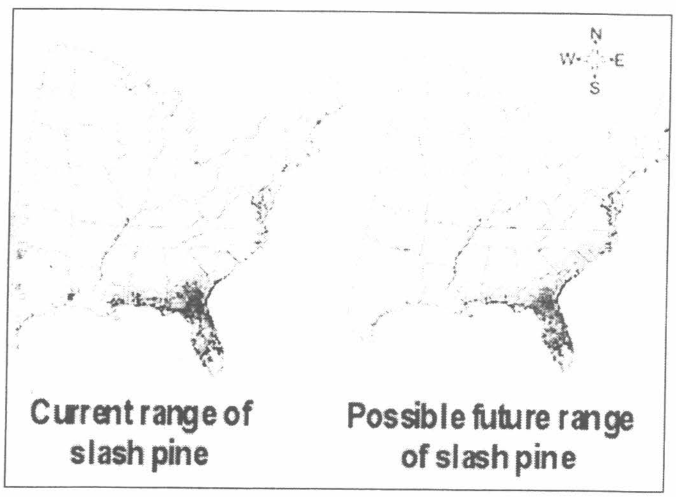
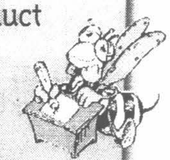


Figure 4. The future preferred habitat for the slash pine tree living in the Southeastern United States will likely move across the south. In which direction is the preferred habitat likely to move? The left map was created from Forestry Inventory and Analysis data, Forest Service. The right map was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

Reflection Section



- 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.

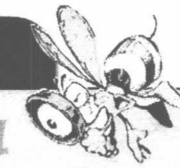
species (spē shēz): Groups of organisms that resemble one another in appearance, behavior, chemical processes, and genetic structure.

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:

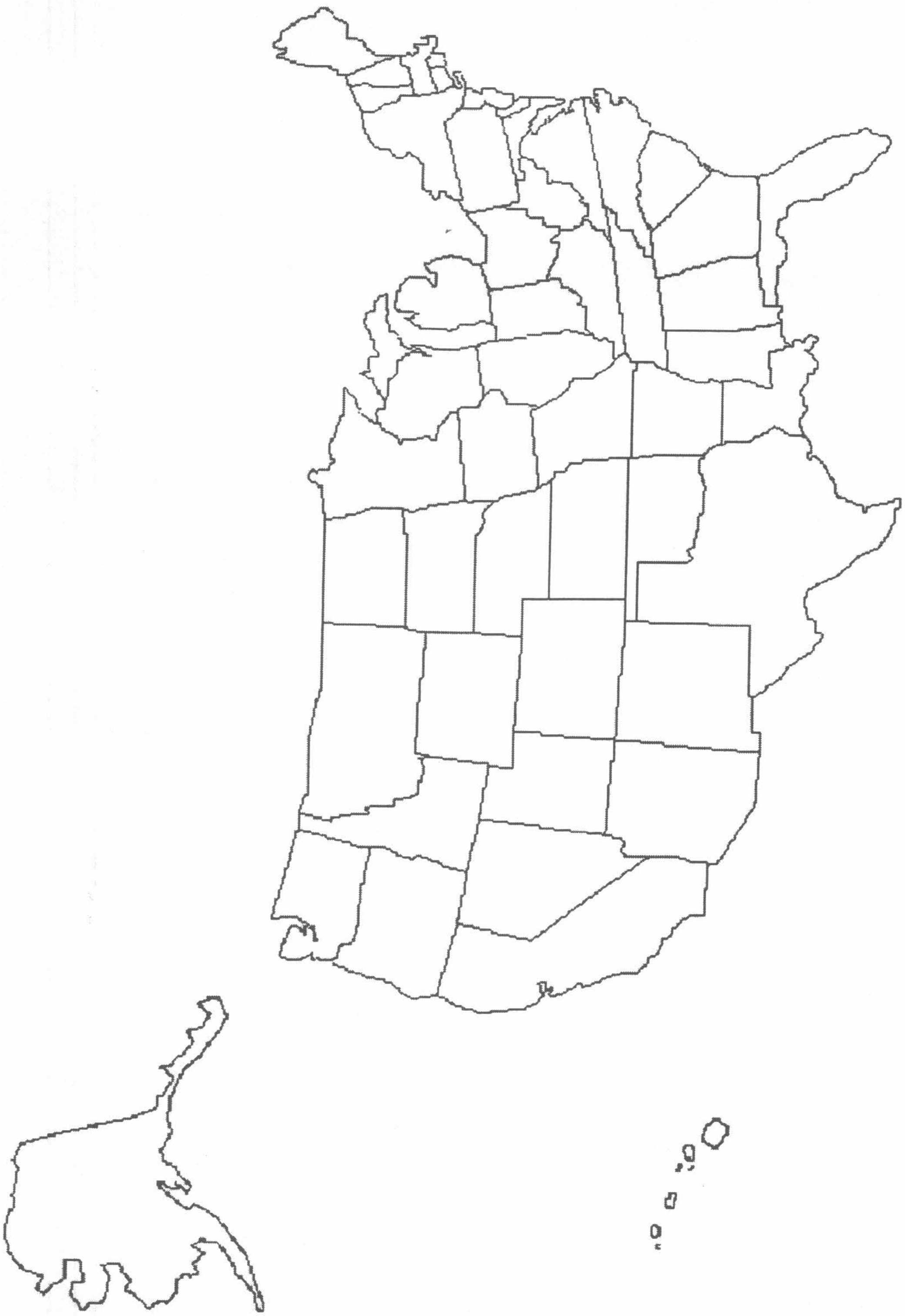
First class period:

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?"

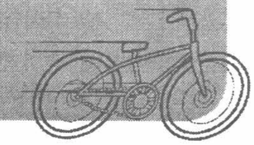
Extensions

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

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 19^{th} 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.

Grade 8: Connecting Research to Outcomes in a Changing Climate

Stage 1 – Desired Results

Outcomes and Indicators:

Continue the study of plant phenology (initiated during grades 6 and 7) by continuing with and augmenting the previous years' research project.

Explore the variety of microclimates on the school campus by investigating temperature, relative humidity, and light availability across the campus.

Test potential plant habitats using the microclimates identified on the school campus by growing native seeds and examining germination and growth measures.

Understand the importance of research in helping find solutions to future impacts of climate change by interacting with a SEGA researcher from NAU/The Arboretum and designing a SEGA experiment.

Identify how changes in the timing of plant phenology can impact animal populations by analyzing historical data of the pied flycatcher and by making inferences based upon that data.

Explore actions humans can take to minimize their impact on climate change by reviewing a list of steps provided by The Arboretum and by understanding the implications of each step.

Assist The Arboretum at Flagstaff by designing interpretive signs for SEGA research projects or the phenology project to be used for public education.

Understandings: *Students will understand that . . .*	**Essential Questions:** *Students will ask such questions as…*
Scientific research is a complex process that requires careful attention to detail, proven research methodology, and accuracy in collection of data.	How do scientists conduct their research? How do we know their results and conclusions are valid?
Plants and animals adapt to life within an ecosystem but some may not be able to adapt if the environment or climate changes too rapidly.	What happens to organisms living within a specific ecosystem if that ecosystem changes in response to a changing climate?
When studying an issue, scientists interpret data and evaluate evidence using the skills of observation, questioning, inferring, and communicating.	What does a scientist do?
Humans can minimize their carbon footprint through conscious decisions.	How can humans mitigate their carbon footprints?
Knowledge:	**Skills:**

Students will know . . .	*Students will be able to . . .*
Scientific research is a long-term process that requires carefully honed skills. Plant and animal species generally require many generations to evolve. Individuals may or may not be able to adapt to new and changing environmental conditions. Scientists must carefully examine their data to ensure reliability and accuracy when investigating an issue or testing a hypothesis. SEGA is a long-term ecological research instrument that can help scientists better understand how plants will respond to a changing climate. Communicating the results of an investigation is of primary importance to the scientific community.	Observe and record the phenology of a plant or plants within the Flagstaff area Examine microclimates on the school campus Develop questions to guide their research Organize data into logical tables, columns, charts, graphs, or other visual displays Identify variables that may impact the timing of a plant's phenology Make inferences about how a changing climate in Flagstaff might affect plants or other organisms that depend upon those plants Hold informed discussions on what it means to mitigate for climate change impacts

Key Vocabulary:

Note for teachers: it will be important that students review vocabulary introduced during grades 6 and 7:

Albedo Effect – Annual – Atmosphere - Biennial - Carbon cycle - Climate – Dendrochronology - Elevation – Greenhouse Effect – Greenhouse Gas – Habitat –Hydrosphere - Lithosphere - Meteorology - Native plant - Perennial - Phenology - Precipitation - Protocol - Qualitative data - Quantitative data – Urban heat island - Weather

Vocabulary for grade 8:

Carbon footprint - A carbon footprint is the measure of the environmental impact of a particular individual or organization's lifestyle or operation, typically measured in units of carbon dioxide (and other greenhouse gases) emitted per year

Citizen Science - is a strategy used by scientists to help augment their body of data and evidence through the training and networking of volunteers who use tested protocols for assisting in a scientific data collection

Hygrometer – a device for measuring humidity

Microclimate - the climate of a very small or restricted area, especially when this differs from the climate of the surrounding area

Migration – movement from one place to another (usually to find the best food supply and not to avoid changes in temperature)

NDVI (Normalized Difference Vegetation Index) – a measurement of how much photosynthesis is occurring at the Earth's surface

Photometer – a device for measuring light availability

Relative humidity - the amount of water vapor present in air expressed as a percentage of the amount needed for saturation at the same temperature

Variable – something that can vary or change

Stage 2 – Assessment Evidence

Performance Tasks:	Other Evidence:
The following are continuing from grades 6 and 7: *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 Completion of *required elements* in the ongoing phenology study (data and evidence in journals). Additional for grade 8: *Collect, analyze,* and *chart data* from a school campus investigation *Design an interpretive sign* for a SEGA research project or the phenology project.	On task with questions Demonstrates enthusiasm for learning Individual motivation and group cooperation Active participation in all class activities Contributes to class discussions individually and as part of a small group

Stage 3 – Action Plan

Learning Activities:

NOTE: Students will continue the long-term phenology project launched in grade 6 and continued in grade 7. Project may expand to include additional species, depending upon the enthusiasm and self-direction of students.

Engage Guiding question: "How much do microclimates vary across my school campus?"

Students explore microclimates for plant growth within their school campus by mapping and documenting temperature, relative humidity and light availability across their campus.

Extension: Add instruments like an anemometer (wind speed), soil probes (pH, soil moisture) or data loggers to more deeply explore differences in microclimate.

Explore Guiding question: "What microclimate provides the best growing conditions for plants?"

Students analyze their microclimate data and test sites by germinating and growing native seeds.

Explain Guiding question: "What is SEGA and how is it being used to study climate change?"

Students identify the role of the SEGA Project to the ecological future of northern Arizona and compare their own research with that of the scientists.

Extension: Plan a field trip to The Arboretum to see the SEGA gardens and research projects, the state-of-the-art weather station, the I-STEM Learning Center and Climate Change Exhibit.

Elaborate Guiding question: "Right place, wrong time…or right time, wrong place?"

Students contemplate the ecological and phenological connections between oak leaves, caterpillars, and Pied flycatchers in Spain. (Ch. 8 Right Place, Wrong Time in *Climate Change from Pole To Pole* – NSTA)

Evaluate Guiding question: "What can we do to help our native plants survive long-term changes in climate?"

Students create interpretive signage for a SEGA research project or the phenology project.

<table>
<tr><th colspan="3">Connecting Research to Outcomes in a Changing Climate
Grade 8: Arizona Academic Standards, Framework for K-12 Science Education, and Climate Literacy Principles</th></tr>
<tr><th>Framework for K-12 Science Education</th><th>Arizona Academic Standards</th><th>Climate Literacy: The Essential Principles of Climate Science</th></tr>
<tr><td>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
LS2.A: Interdependent Relationships in Ecosystems
LS2.C: Ecosystem Dynamics,</td><td>Science
S1C1PO2. Select appropriate resources for background information related to a question, for use in the design of a controlled investigation.
S1C2PO 1. 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).
S1C1PO5. 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).
S1C3PO5. Explain how evidence supports the validity and reliability of a conclusion.
S1C3PO7. Critique scientific reports from periodicals, television, or other media.
S1C3PO8. Formulate new questions based on the results of a previous investigation.
S1C4PO1. Communicate the results of an investigation.
S1C4PO2. Choose an appropriate graphic representation for collected data:
• line graph
• double bar graph
• stem and leaf plot</td><td>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.
C. Changes in climate conditions can affect the health and function of ecosystems and the survival of entire species. The distribution patterns of fossils show evidence of gradual as well as abrupt extinctions related to climate change in the past.
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 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. .
6. Human activities are impacting the climate system.</td></tr>
</table>

Functioning, and Resilience LS4.B: Natural Selection LS4.C: Adaptation LS4.D: Biodiversity and Humans Earth and Space Science ESS2.C: The Roles of Water in Earth's Surface Processes ESS2.D: Weather and Climate ESS3.C: Human Impacts on Earth Systems ESS3.D: Global Climate Change	• histogram **S1C4PO3**. Present analyses and conclusions in clear, concise formats. **S1C4PO5**. Communicate the results and conclusion of the investigation. **S2C2PO1**. Apply the following scientific processes to other problem solving or decision making situations: • Observing • Questioning • Communicating • Predicting • Organizing data • Inferring • Generating hypothesis • Identifying variables NOTE: Classifying is a part of this PO but is not addressed in this lesson. **S2C2PO3**. Defend the principle that accurate record keeping, openness, and replication are essential for maintaining an investigator's credibility with other scientists and society. **S2C2PO4**. Explain why scientific claims may be questionable if based on very small samples of data, biased samples, or samples for which there was no control. **S3C2PO1.** Propose viable methods of responding to an identified need or problem. **S3C2PO2**. Compare solutions to best address an identified need or problem. **S4C4PO1.** Explain how an organism's behavior allows it to survive in an environment. **S4C4PO3**. Determine characteristics of organisms that could change over several generations. **S4C4PO4**. Compare the symbiotic and competitive relationships in organisms within an ecosystem (e.g., lichen, mistletoe/tree, clownfish/sea anemone, native/non-native species). **S4C4PO6**. Describe the following factors that allow for the survival of living organisms:	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. 7. Climate change will have consequences for the Earth system and human lives. E. Ecosystems on land and in the ocean have been and will continue to be disturbed by climate change. Animals, plants, bacteria, and viruses will migrate to new areas with favorable climate conditions. Infectious diseases and certain species will be able to invade areas that they did not previously inhabit.

	• seed dispersal • pollination Note: Beak design and protective coloration are a part of this performance objective but is not addressed in this lesson. **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)** Distinguish among facts, reasoned judgment based on research findings, and speculation in a text. (**6-8.RST.8**) **AZ College and Career Readiness Standards – Math** Mathematical Practices **8.MP.1.** Make sense of problems and persevere in solving them. **8.MP.2.** Reason abstractly and quantitatively. **8.MP.3.** Construct viable arguments and critique the reasoning of others. **8.MP.4.** Model with mathematics. **8.MP.5**. Use appropriate tools strategically. **8.MP.6**. Attend to precision. **8.MP.7.** Look for and make use of structure. **8.MP.8**. Look for and express regularity in repeated	

	reasoning. **Technology** **Creativity and Innovation** **S1C1PO1** Analyze information to generate new ideas and products. **S1C3PO1** Identify patterns and trends to draw conclusions and forecast possibilities. **S1C4PO2** Use digital collaborative tools to analyze information to produce original works and express ideas. **Communication and Collaboration** **S2C2PO1** Communicate and collaborate for the purpose of producing original works or solving problems. **Digital Citizenship** **S5C2PO1** Promote digital citizenship by consistently leading by example and advocating social and civic responsibility.	

Materials Required – Grade 8: Connecting Research to Outcomes in a Changing Climate

Websites*:*

- https://www.usanpn.org/nn/species_search (National Phenology Network)
- www.sega.nau.edu (Southwest Experimental Garden Array)
- http://mprlsrvr1.bio.nau.edu:8080/?command=RTMC&screen=Arboretum%20at%20Flagstaff (Arboretum meadow SEGA weather station data)

Books/media:

- *Integrating climate change and genetic research to restore western landscapes* (Arboretum brochure)
- *Climate Change Is Happening…What It Is and What You Can Do* (Arboretum brochure)

Photocopies:

- School maps (1/team)
- Ch. 8 Right Place, Wrong Time in *Climate Change from Pole To Pole* – NSTA
  - Reporting form - student page 8.1 (24 copies)
  - Consensus form - student page 8.2 (6 copies)
  - Figure 8.3 (1 copy/small group OR use document camera to present)
  - Data sets 1 through 6 (1 copy of each)
- *Phenology in Your Backyard* Guide

Science equipment:

- Thermometer (1)
- Relative humidity meter (1)
- Light meter (1)

Art supplies:

- White construction paper (9"x12" – 1 sheet for every student or small group)
- Colored pencils and/or markers
- White poster board (9"x12" – 1 sheet for every student or small group)

Miscellaneous:

- Journals for students [**or** add to science notebooks if already being used]
- Document camera (in lieu of copies of Figures 8.1 and 8.2)
- 6 large manila envelopes
- Yardstick or measuring tape (1/team)
- Clipboards (1/team – if not using journals)
- Graph paper
- 12 plastic 1 gallon flower pots (Request from The Arboretum at Flagstaff)
- Potting soil
- Native plant seeds (Request from The Arboretum at Flagstaff)

Grade 8: Connecting Research to Outcomes in a Changing Climate

Subject & Topic

Science and ACCP – adaptations, climate change

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 8 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

LS2.A: Interdependent Relationships in Ecosystems

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

LS4.B: Natural Selection

LS4.C: Adaptation

LS4.D: Biodiversity and Humans

Earth and Space Science

ESS2.C: The Roles of Water in Earth's Surface Processes

ESS2.D: Weather and Climate

ESS3.C: Human Impacts on Earth Systems

ESS3.D: Global Climate Change

Objectives

1. Continue the study of plant phenology (initiated during grades 6 and 7) by continuing with and augmenting the previous years' research project.
2. Explore the variety of microclimates on the school campus by investigating temperature, relative humidity, and light availability across the campus.

3. Investigate potential habitats for plants by examining the microclimates identified on the school campus and explaining their suitability for various species.
4. Understand the importance of research in helping find solutions to future climate change impacts by reviewing the role of the SEGA Project to northern Arizona's ecological future and by examining SEGA research projects.
5. Identify how changes in the timing of plant phenology can impact animal populations by analyzing historical data of the pied flycatcher and by making inferences based upon that data.
6. Assist The Arboretum at Flagstaff by creating interpretive signs for a SEGA research project or the phenology project.

Evidence of Mastery

The following four are a continuation from grades 6 and 7 (phenology research project):

- *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
- Completion of *required elements* in the ongoing phenology study (data and evidence in journals).

Additional for grade 8:

- *Collect, analyze, and chart data* from a school campus investigation
- *Design interpretive signs* for a) an exisiting SEGA research project, or b) your phenology project.

Key vocabulary:

Review and reinforce vocabulary learned during Grades 6-7

Albedo Effect
Annual
Atmosphere
Biennial
Carbon cycle
Climate
Dendrochronology
Elevation
Greenhouse Effect
Greenhouse gas
Habitat
Hydrosphere
Lithosphere
Meteorology
Native plant
Perennial

Materials: (items and quantities)

Websites:

- http://sega.nau.edu (Southwest Experimental Garden Array)
- https://www.usanpn.org/nn/species_search (National Phenology Network)
- http://mprlsrvr1.bio.nau.edu:8080/?command=RTMC&screen=Arboretum%20at%20Flagstaff (Arboretum meadow SEGA weather station data)

Books/media:

- *Integrating climate change and genetic research to restore western landscapes* (SEGA brochure)
- *Climate Change Is Happening…What It Is and What You Can Do* (Arboretum brochure)

Photocopies:

- School maps (1/team)

Phenology
Precipitation
Protocol
Qualitative data
Quantitative data
Urban heat island
Weather
Additional vocabulary for grade 8

- *Carbon footprint* - A carbon footprint is the measure of the environmental impact of a particular individual or organization's lifestyle or operation, typically measured in units of carbon dioxide (and other greenhouse gases) emitted per year.
- *Citizen Science* - is a strategy used by scientists to help augment their body of data and evidence through the training and networking of volunteers who use tested protocols for assisting in a scientific data collection.
- *Hygrometer* – a device for measuring humidity.
- *Microclimate* - the climate of a very small or restricted area, especially when this differs from the climate of the surrounding area.
- *Migration* – movement from one place to another (usually to find the best food supply and **not** to avoid change sin temperature)
- *NDVI (Normalized Difference Vegetation Index)* – a measurement of how much photosynthesis is occurring at the Earth's surface
- *Photometer* – a device for measuring light availability.
- *Relative humidity* - the amount of water vapor present in air expressed as a percentage of the amount needed for saturation at the same temperature.
- *Variable* **–** something that can vary or change

- *Ch. 8 Right Place, Wrong Time in* Climate Change from Pole To Pole – *NSTA*
  - Reporting form - student page 8.1 (24 copies)
  - Consensus form - student page 8.2 (6 copies)
  - Figure 8.3 (1 copy/small group OR use document camera to present)
  - Data sets 1 through 6 (1 copy of each)
- *Phenology in Your Backyard* Guide

Science equipment

- Thermometer (1/team)
- Relative humidity meter (1/team)
- Light meter (PAR) (1/team)

Art supplies:

- White construction paper (9"x12" – 1 sheet for every student or small group)
- Colored pencils and/or markers
- White poster board (9"x12" – 1 sheet for every student or small group)

Miscellaneous:

- Document camera (in lieu of copies of Figures 8.1 and 8.2)
- 6 large manila envelopes
- Photos of birds native to your area (1/every student – all different species if possible)
- Yardstick or measuring tape(1/team)
- Clipboards (1/team – if not using journals)
- Graph paper
- 12 plastic 1 gallon pots
- Potting soil (1-2 bags)
- Native plant seeds (Request from The Arboretum at Flagstaff)

Engage

Guiding question: "How much do microclimates vary across my school campus?"

Prepare:

- Discuss different characteristics of climate and how the chosen characteristics will be measured today. Go over use of instruments and units of measure. Include in your discussion the importance of physically describing the microclimate surroundings. **For example**, black pavement may heat up a microclimate, whereas white concrete might cool a microclimate (Albedo Effect).
- Divide class into four teams.
- Create an 8½" x 11" perimeter map of your school campus, noting specific landmarks (streets, school building, etc.). You may choose to include a section where teams will identify date, time, weather conditions, team members, etc.
- Make copies of the map (1 copy/each team)
- Draw the outline of the school campus on the board (for share outs later in the lesson)
- Decide which group will be measuring temperature, light, relative humidity and making physical descriptions.
- Gather supplies: each group receives the appropriate "meter" and clipboards (if needed), a yardstick or measuring tape, graph paper for data collection and the map
- Calibrate thermometers (or plan to do this as a first step with students) to ensure accuracy of results [Place all thermometers into a beaker of ice water for 5 minutes. All should read between 0.0° to 0.5° C. [If there is greater variation, select one to use as your comparison point. Note how much each of the others differs and plan to incorporate that amount into final calculations.]
- As a class – choose four sites around campus, **that you feel would provide optimal growing conditions for plants**, to measure microclimate. Mark these sites on everyone's map. Sites should be at least 20 feet apart.

Present:

- Ask: "Are the chosen site locations truly different microclimates? How can we find out?"
- Assign one of the chosen sites of the school campus to each team. Data should be collected on the datasheet provided.
- Ask: "What details should we include on our data sheet? To be consistent, what do we need to remember?" [Discuss the importance of all teams taking measurements at the same place within their assigned site, being sure to identify the height of the thermometer – e.g., on the ground, 6' off the ground, etc. – and the citation of other details such as date, time, names of team members, weather conditions, etc.]

Student activity:

- **Remind students of safety procedures to follow at all times while outdoors.**
- In their teams, students take their measurements or make their descriptions. Provide at least 15 minutes per site. Afterwards, groups should rotate to the next site on their map and repeat the exercise until all four sites have been examined. **Note:** depending on the available amount of time, you may want to select campus sites that are

relatively close together.

- For those groups with meters, a reading from the instrument should be taken once every minute for a total of 10 minutes (= 10 measurements). Remind them to keep the meter in the same location for all 10 measurements.
- Back in the classroom, have students share their data. Each team should identify the highest and lowest measurement and the site description.
- Each team should create a chart, table or graph to demonstrate the variability within the data collected. Make sure that each team gets the data from the other team. Students should calculate averages.
- Ask: "Is there variation within your set of measurements for a site? Why or why not? Do your measurements across sites differ?" [Encourage answers such as shady vs. open areas, irrigated vs. non-irrigated areas, higher elevation than another, sun was shining on this spot longer than another, user error, etc.]. Repeat the question for each type of measurement and the site description.
- Explain that each of these small areas can be considered a "microclimate" or a smaller version of the Earth's climate. Microclimates can be affected by natural events (sunshine, wind, moisture, plant cover) and by manmade factors (buildings, sidewalks, paved areas, brickwork, etc.).
- Have the groups each choose a *site* and summarize ALL of the collected data for that site to turn in.

Ask: "How much variation did we find across our campus? Why do you think that is the case? If the temperatures continue to rise, what responses might you expect to see in plants? In animals?"

Make sure you collect the maps and datasheets and summaries created by the student teams. (It would be helpful to scan these into a computer for future reference.)

Extension: Adding instruments like an anemometer (wind speed), soil probes (pH, moisture, temperature), and/or data loggers will provide additional scientific data that students can use in their explorations.

Explore

Guiding question: "What microclimate provides the best growing conditions for plants?"

Prepare:

- Make copies of the four-school site summaries provided by each team in the **Engage** activity. Randomly distribute a school site summary and map to each of the four groups.
- In their groups, have students make a list of pros and cons pertaining to plant growth relative to their group's site summary and map. Use these lists for the following discussion on plant growth requirements.

Present:

- Ask: "Which microclimate will provide the best growing environment for plants?"
- Discuss the growing requirements of different plants. Encourage responses that include the necessities for life: food, water, shelter, space – this is also a good place to review plant adaptations.
- Explain that students will be growing native plants in the selected campus sites to determine which microclimate is best for growing plants.

Student activity:

- Gather the following materials and divide equally among the four groups: (12) identical 1 gallon plastic pots; (2) bags of potting soil; masking tape for labeling pots; native plant seeds*. **Note:** seeds and planting instructions can be acquired from The Arboretum at Flagstaff or can be purchased.
- Students should label each of their 3 pots with their campus location, group member names, and unique replicate number (1, 2 or 3). Afterwards, pots should be filled ¾ full with potting soil and the students should follow the planting protocol for their seeds. Discuss the importance of treating each pot the same.
- Once the seeds have been watered in – groups should place their 3 replicate pots in their microclimate site.
- ALL pots should receive the same amount of water daily – see the planting protocol for how much water this should be. Students should make observations on their pots as many times as possible per week, for up to three weeks. Most seeds should germinate in ~10 days.
- Observations should be recorded in journals. At the end of the growing period (teacher determined) – students will summarize their observations and share these data with the class.

Ask: "Which microclimate supported the highest seed germination? The least seed germination? The biggest seedlings?"

Encourage discussion as to which microclimate provided the best growing conditions.

Ask: "How would you explain the variation across microclimates?" Refer to their microclimate measures. "Did you see variation within your microclimate? What might cause this?"

Have students generate possible reasons to explain growth differences across and within microclimates.

Explain

Guiding question: "What is SEGA and how is it being used to study climate change?"

Prepare:

- Invite a guest speaker by contacting the Director of Research at The Arboretum at Flagstaff. The Arboretum can provide a current list of SEGA researchers and help identify a speaker for your classroom. Ask the speaker to include: an overview of the SEGA Project (intended outcomes, protocols, how scientists are/will be using data),

data gathered thus far and its implications for the future, how anticipated climate change might affect plants of northern Arizona and, if known, how other species that depend upon those plants might be affected.

- Distribute the Arboretum brochure, *Integrating climate change and genetic research to restore western landscapes*

Present:

- Introduce the guest speaker to the class. Include a brief bio of the person's background: special interests/hobbies, classes that helped them prepare for their career, what they enjoy about being a scientist. (You might ask the presenter to include this information prior to his/her presentation, rather than offering this information yourself.)

Student activity:

- Attentively listen to the presentation.
- Ask questions about SEGA and research.
- Have students work in groups to design a SEGA experiment by asking, "How would you re-design the campus study of microclimate and native plant germination and growth using SEGA?" Once the ideas are down on paper – discuss the pros and cons of each experiment as a class.

Extension: Plan a field trip to The Arboretum at Flagstaff to see the SEGA gardens and research projects, the state-of-the-art weather station, the Climate Change Learning Center and Exhibit.

Elaborate

Guiding question: "Right place, wrong time…or right time, wrong place?"

Note: The activity is adapted from the NSTA resource *Climate Change from Pole to Pole.*

Part I

Prepare:

- Review Chapter 8: "Right Place, Wrong Time – Phenological Mismatch in the Mediterranean" for background information.
- Divide class into small groups (2-5 students/group).
- Assign the following roles to each group: *note taker* (will record group's thoughts on each data set), *timekeeper* (will monitor the time and keep group on task), *student representative* (communicates with the teacher if the group has questions), *presenter* (communicates the group's responses to the rest of the class), *discussion leader* (optional – leads group's discussion).
- Copy Figure 8.1 (24 copies) and Figure 8.2 (1 copy/group OR plan to use document camera)

Present:

Facilitate a brief discussion for the following:

- "What is migration? Do all birds migrate?" [movement from one place to another, usually to find a more suitable or available food source; not all birds migrate]
- "What do birds eat when they are migrating?" [whatever might be available *en route*!]
- "Are some foods better for birds than others? Do birds eat the same food all year long? How might plants impact the food selection of migrating birds?" [many animals eat different foods, consuming whatever might be available to them each season – e.g., squirrels, bears, coyotes all eat different foods depending on the time of year and what is in nature's pantry]

Student activity:

- Students consider Figure 8.1. What is the "big idea" behind this diagram?
- Students then read Figure 8.2. Each group identifies 2 or more challenges that pied flycatchers might face during their spring migration.
- The presenter for each group shares its group's ideas with the class. Facilitate a brief discussion on the collective results.

Part II

Prepare:

- Copy figure 8.3 (1 copy/group) OR use document camera

Present:

- Present figure 8.3 to the class (document camera or photocopy)
- Ask: "What is the connection between oak leaves, pied flycatchers, and caterpillars?" and "What might happen if oak leaves developed earlier than usual, well prior to the birds arrival each spring?" (This is a likely result of climate change.)

Student activity:

- Students consider the ecological and phenological connections between the oak leaf, caterpillar, and pied flycatcher in Spain.
- The presenter for each group shares key elements of its discussion with the class.
- Encourage students to try to think of other relationships between plants and other insects, birds, mammals).

Part III

Prepare:

- Prepare packets for group review: insert one data set into each of six different manila envelopes along with *four* copies of Student Reporting Form (Page 8.1) and *one* copy of Student Consensus Form (Page 8.2).

Present:

- Write the following question on the board: "Is there a relationship between high spring temperatures and the breeding success of pied flycatchers?"

- Explain to students that they will be exploring data collected by researchers in Spain over a period of 18 years. **Not all data gathered may be relevant to this question.**
- Distribute one manila packet to each group. Remind them to remain in their assigned roles while they answer all questions on their reporting form. They will have 5-10 minutes (teacher's choice!) to consider and record their responses to the data – and only these data - in their packet.

Student activity:

- Each group reviews its data set within the time frame allocated and files its report in the manila envelope.
- Each envelope is passed to the next group (or groups move from table to table) and the process is repeated. *Students should NOT use any time to read a prior group's responses. This will occur later. (Teachers may need to monitor this.)*
- Repeat three more times until each group has seen four (4) different data sets.
- Groups pass the manila packet they last considered to the next team.
- Rather than reviewing this data set and completing a Reporting Form as before, each group will review all four Reporting Sheets for the data set in their hands, consolidate the interpretations, and add details or make changes they view necessary on the Consensus Form – Page 8.2. (This may require deciding between conflicting decisions! The presenter for each group should be ready to defend his/her group's consensus.) Additional time may be allocated to this rotation if necessary, allowing the groups time to seriously consider differences of opinion that may exist.
- Starting with data set 1, each group briefly identifies what the variables were, their relationship with each other, and (by consensus of the team) whether that data set supports, rejects, or does neither for the original hypothesis posted on the board.

Ask: "Why is it important to have both quantitative and qualitative data when considering the issue of climate change?" Facilitate a brief discussion.
Ask: "How does a warming climate impact not only a plant but also other species that depend upon that plant?"

Evaluate

Guiding question: "What can we do to help our native plants survive long-term changes in climate?"

Part I

Prepare:

- Work with The Arboretum liaison to gather all data collected from all classes participating in the phenological research project.
- Collect corresponding weather data from the SEGA Arboretum weather station.
  http://mprlsrvr1.bio.nau.edu:8080/?command=RTMC&screen=Arboretum%20at%20Flagstaff
- Provide *Climate Change Is Happening…What It Is and What You Can Do* (Arboretum brochure) – 1 copy for every team member

Present:

- Share the aggregated phenology data and weather data with students. Ask them to create a graph, chart, or table that will begin (over time) to show trends. [This should be a visual that can be shared with the community, either via The Arboretum or classroom website or at an Arboretum kiosk. It should be presented so that any visitor to the site can easily see the research being undertaken by the students, what they are observing, and – over time – what they can infer from the data.]

Student activity:

- In teams, students create a visual (chart, graph, table) that portrays the data gathered.
- Ask: "How is the research we are doing today providing evidence that climate scientists can use 100 years from now?" Facilitate a brief discussion.
- Ask: "How do humans contribute to climate change?" [Students should refer to The Arboretum's guide *Climate Change is Happening*… and recall their activities from grades 6 and 7, especially remembering how we contribute to the greenhouse effect and how carbon is moved throughout the planet and atmosphere.] Facilitate a brief discussion.
- Each student team reviews suggestions provided by The Arboretum guide. Ask: "What steps can we take now to help minimize our carbon footprint [how we are adding to climate change]? What does each of these suggestions have to do with climate change? Do you have any addiitonal ideas or suggestions for steps we can take?" [Students may not understand that an incandescent light bulb provides 10% radiant (light) energy and 90% thermal (heat) energy when lit. CFL and LED bulbs are far more efficient! Water has a great deal of energy embedded in its delivery to us: electricity to pump raw water to be treated before it can be used for potable purposes, energy to pump the water to our homes, then back into the sewer system to be pumped to a water treatment plant, etc. It is important that students be able to draw connections between their daily activities and the resulting impacts upon the planet.]

Part II

Prepare:

- Work with Arboretum research staff to identify ongoing research projects in the SEGA gardens OR use the phenology project data to develop interpretive signs for the public.
- Gather art supplies for each student or small group.

Present:

- Explain to students that they (individually or in small groups) will be creating an interpretive sign to be displayed at The Arboretum. The purpose of this is to help the general public become more aware of the role of on-going research and the potential implications of those studies on how we manage landscapes.
- Information to be included on each interpretive sign will be: 1) The researcher(s) name and home institution, 2) the research question being addressed, 3) brief methods being used by the researcher, and 4) anticipated data and results and potential implications for land management. It will be helpful to include photos or drawings of

the experimental design, plants being studied, and any graphs or figures that might help explain what is being done.

Student activity:

- Design an interpretive sign that addresses all of the listed criteria.

Closure: (revisit objective, IQ's and make real world connections)

Students review their phenology data collected over the past three years, comparing and contrasting the data they collected with that of other project participants. Chart or graph the results. (This will form the basis for a long-term study among current and future students.)

Drawing inferences from their own data, what predictions would they make about what might happen if climate change continues unabated in northern Arizona?

What can they do to help minimize their own carbon footprint while helping build a body of sound science to guide future decision makers?

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 S1C1PO1 S1C2PO1, PO4, PO5 S1C3PO1 and PO5 S1C4PO1, PO2, PO3, PO5 S2C2PO1, PO3, PO4 S4C4PO1	**ENGAGE – ACCR** 6-8.RST.3 6-8.RST.4	**ENGAGE – Math** 8.MP.2 8.MP.5 8.MP.6 8.MP.8	**ENGAGE – Technology** S1C1PO1 S1C3PO1 S2C2PO1
EXPLORE – Science S1C2PO1, PO4, PO5 S1C3PO1, PO2 S1C4PO1 S2C2PO1 S3C2PO1 and PO2 S4C4PO6	**EXPLORE – ACCR** 6-8.RST.3	**EXPLORE – Math** 8.MO.6 8.MP.7	**EXPLORE – Technology** S1C1PO1 S1C3PO2 S2C2PO1
EXPLAIN – Science (Contingent upon guest speaker) S1C1PO2 S1C3PO5 and PO8 S2C2PO1 and PO4 S4C4PO1 and PO3	**EXPLAIN – ACCR** None	**EXPLAIN – Math** None	**EXPLAIN – Technology** None
ELABORATE – Science S1C1PO1 and PO5 S1C3PO1, PO2, PO5, PO7 S1C4PO1 and PO3 S2C2PO1, PO3, PO4 S2C2PO1, PO3, PO4 S4C4PO1, PO3, PO4	**ELABORATE – ACCR** 6-8.RST.1 6-8.RST.3 6-8.RST.4 6-8.RST.7 6-8.RST.8	**ELABORATE – Math** 8.MP.2 8.MP.3 8.MP.4 8.MP.6 8.MP.7 8.MP.8	**ELABORATE – Tech.** S1C1PO1 S1C3PO1
EVALUATE – Science (dependent upon option selected) S1C1PO2 S1C4PO1, PO2, PO3, PO4, PO5 S4C4PO6	**EVALUATE – ACCR** (dependent upon option selected) 6-8.RST.3 6-8.RST.4 6-8.RST.7	**EVALUATE – Math** 8.MP.5 8.MP.6	**EVALUATE – Tech.** (dependent upon option selected) S1C4PO2 S2C2PO1 S5C2PO1

Science

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

S1C2PO 1. *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).*

S1C1PO5. *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).*

S1C3PO5. Explain how evidence supports the validity and reliability of a conclusion.

S1C3PO7. Critique scientific reports from periodicals, television, or other media.

S1C3PO8. Formulate new questions based on the results of a previous investigation.

S1C4PO1. Communicate the results of an investigation.

S1C4PO2. *Choose an appropriate graphic representation for collected data:*

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

S1C4PO3. Present analyses and conclusions in clear, concise formats.

S1C4PO5. *Communicate the results and conclusion of the investigation.*

S2C2PO1. Apply the following scientific processes to other problem solving or decision making situations:

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

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

S2C2PO3. Defend the principle that accurate record keeping, openness, and replication are essential for maintaining an investigator's credibility with other scientists and society.

S2C2PO4. Explain why scientific claims may be questionable if based on very small samples of data, biased samples, or samples for which there was no control.

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

S3C2PO2. *Compare solutions to best address an identified need or problem.*

S4C4PO1. Explain how an organism's behavior allows it to survive in an environment.

S4C4PO3. Determine characteristics of organisms that could change over several generations.

S4C4PO4. Compare the symbiotic and competitive relationships in organisms within an ecosystem (e.g., lichen, mistletoe/tree, clownfish/sea anemone, native/non-native species).

S4C4PO6. Describe the following factors that allow for the survival of living organisms:

- seed dispersal
- pollination

Note: Beak design and protective coloration are a part of this performance objective but is not addressed in this lesson.

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)**

Distinguish among facts, reasoned judgment based on research findings, and speculation in a text. (**6-8.RST.8**)

AZ College and Career Readiness Standards – Math

Mathematical Practices

8.MP.1. Make sense of problems and persevere in solving them.
8.MP.2. Reason abstractly and quantitatively.
8.MP.3. Construct viable arguments and critique the reasoning of others.
8.MP.4. Model with mathematics.
8.MP.5. Use appropriate tools strategically.
8.MP.6. Attend to precision.
8.MP.7. Look for and make use of structure.
8.MP.8. Look for and express regularity in repeated reasoning.

Technology

Creativity and Innovation

S1C1PO1 Analyze information to generate new ideas and products.

S1C3PO1 Identify patterns and trends to draw conclusions and forecast possibilities.

S1C4PO2 Use digital collaborative tools to analyze information to produce original works and express ideas.

Communication and Collaboration

S2C2PO1 Communicate and collaborate for the purpose of producing original works or solving problems.

Digital Citizenship

S5C2PO1 Promote digital citizenship by consistently leading by example and advocating social and civic responsibility.

Rubric: Interpretive Sign for The Arboretum – Grade 8

Indicator	4: Exceeds expectations	3: Meets expectations	2: Approaches expectations	1: Falls short of expectations
Scientific Accuracy	All content is scientifically accurate and used in proper context. No obvious errors are evident.	Most content is scientifically accurate and used in proper context. 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.
Elements	Includes all required elements: • photo or drawing (with citation of source) • Researcher(s) name and institution. • Introduction to project • Methods • Results/Potential Impacts • Management application	Includes 5 of the required elements. Citation of source of photo or drawing may be missing.	Includes 3-4 of the required elements. Citation of source of photo or drawing may be missing.	Includes 2 or fewer of the required elements. Citation of source of photo or drawing may be missing.
Audience Appeal	Design is visually appealing, creative, and encourages additional questions or consideration for purchase or propagation.	Design is visually appealing, creative, and provides an opportunity for additional questions.	Design may lack visual appeal, creativity, and/or indicates a lack of preparation.	Design lacks visual appeal and creativity. Demonstrates a lack of forethought and preparation.

Chapter 8 Right Place, Wrong Time

Phenological mismatch in the Mediterranean

Teacher Pages

AT A GLANCE

Songbirds tend to breed at the same time their primary prey is most abundant. Climate warming appears to be disrupting this match, causing reproductive failures in some species. Scientists have detected the consequences of warming for birds primarily through correlational studies. In this activity, students work in small groups and as a class to investigate "correlation versus causation." (Class time: 1–2.5 hours)

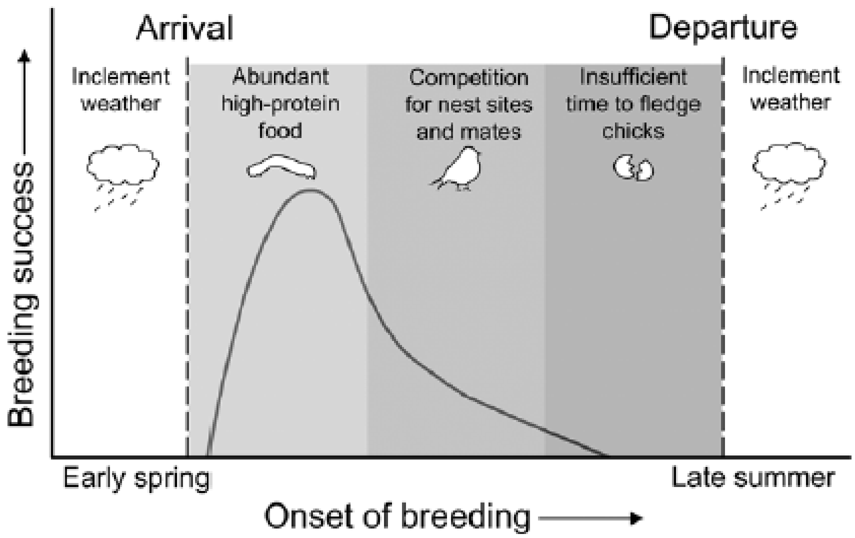
INTRODUCTION

Migration is the seasonal movement of animals from one habitat to another. Animals must time their spring migrations to match the availability of food, territories, and mates in their breeding habitat (Ramenofsky and Wingfield 2007; Figure 8.1). Precise timing is particularly important for species that breed at high latitudes and altitudes, where summers are short and spring conditions are variable (Jonzén, Hedenström, and Lundberg 2007). Climate change appears to be compromising the ability of songbirds to synchronize migratory activities with resource availability (Parmesan 2006). Some species, like the pied flycatcher (Figure 8.2), are suffering population declines because they are not breeding when their preferred prey is most abundant (Both et al. 2006).

In this directed inquiry, small groups of students work cooperatively to examine the effects of climate change on the phenology (i.e., timing of life cycle events; see Chapter 3 for more details) of pied flycatchers. By the end of the lesson, students should be able to

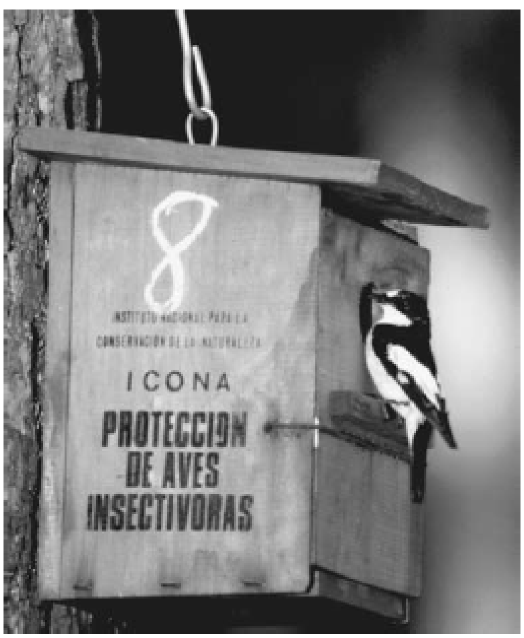
- recognize that a mathematical association between two variables does not necessarily imply that one of the variables is causing a change in the other; and
- explain how different trophic levels in a food chain may respond differently to climate change.

Figure 8.1



Migrating songbirds are more successful when they match their spring arrival, breeding activities, and fall departure to resource availability.

Figure 8.2



Pied flycatcher (*Ficedula hypoleuca*).

Pied flycatchers are insectivorous, cavity-nesting songbirds that breed across the Palaearctic (Europe, northern Africa, and northern Asia). They spend their winters in forests and savannahs in west Africa, south of the Sahara Desert. Adults weigh 12–13 g. Although some flycatchers live up to seven years, adult survival each year is only 40–50% (Lundberg and Alatalo 1992). The subjects of this activity are pied flycatchers that breed in the mountains of Spain. The Spanish pied flycatchers typically arrive in early May and start laying eggs 2–26 days later (Potti 1999). Females lay one clutch of 4–7 eggs per season (Moreno et al. 1995).

Although there are no pied flycatchers in North America, we have 67 other related species. You can find your local flycatcher on eBird at *http://ebird.org/ebird/eBirdReports?cmd=Start*.

At left, an adult male visits an artificial nest box.

Photograph courtesy of Juan José Sanz.

TIMING IS EVERYTHING

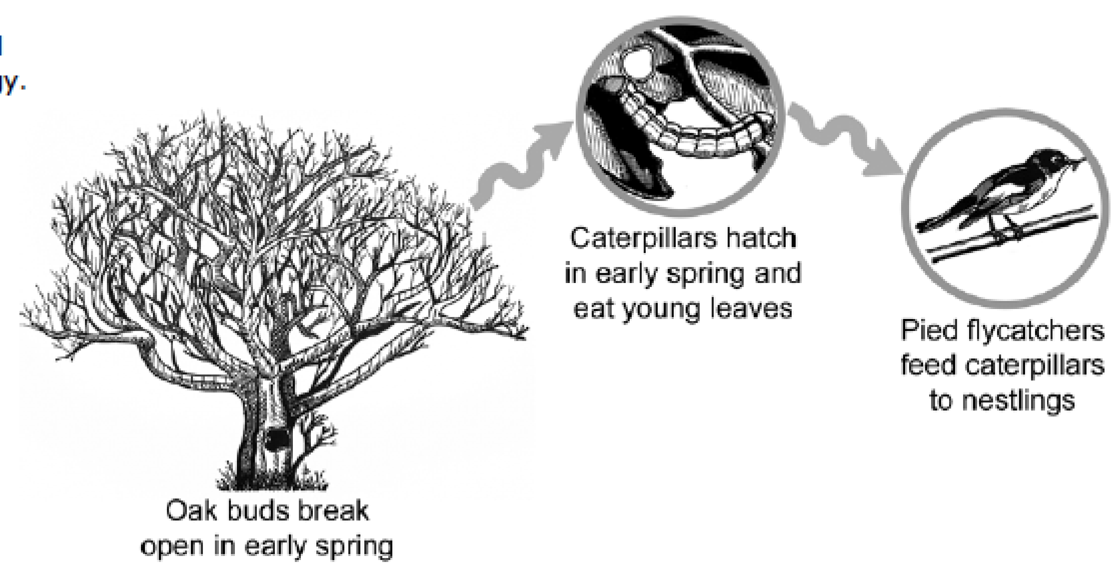
Pied flycatchers, like most long-distance migrants, use seasonal changes in day length and an internal biological clock to initiate migration. Once en route to their breeding grounds, flycatchers may use other environmental cues to refine their behavior (Ramenofsky and Wingfield 2007). For example, cold weather along the migration route tends to slow (or even reverse) their progress north, whereas warm weather tends to accelerate it (Both, Bijlsma, and Visser 2005).

When female pied flycatchers reach their breeding grounds, they usually mate and lay eggs within one or two weeks (Potti 1999). Under the most optimal conditions, chicks will hatch when caterpillars—which are high in protein and easy to digest—are most abundant (Martin 1987). In deciduous forests where flycatchers nest, the phenology of caterpillars is synchronized with the phenology of host trees (Buse et al. 1999) (Figure 8.3). The leaves of trees such as oaks become less palatable and nutritious as they mature, so there is strong selective pressure for caterpillars to hatch at the same time tree buds break open (van Asch and Visser 2007). It appears that over the last few decades, forest caterpillars have been emerging earlier and developing faster in response to warming temperatures (Both et al. 2006).

Although some populations of pied flycatchers (e.g., in Denmark) have adjusted to changes in caterpillar phenology by advancing their spring activities, others are suffering a "phenological mismatch" with their prey (Both et al. 2004). For instance, pied flycatchers in

Figure 8.3

Synchronization of oak, caterpillar, and flycatcher phenology.

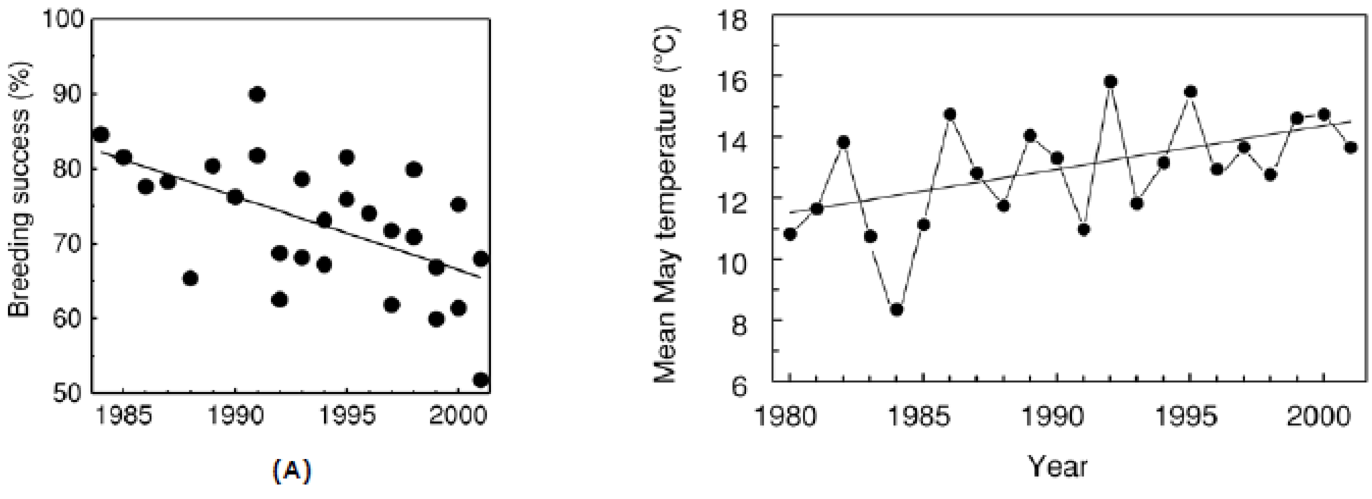


central Spain are breeding too late to take advantage of peak caterpillar abundance. When clutches are laid too late, parents are forced to feed chicks prey such as grasshoppers and beetles, which are lower in nutrients and likely to slow development of chicks (Wright et al. 1998). Over the last two decades, the Spanish populations of pied flycatchers have been producing fewer and lighter **fledglings** (young birds that can fly but are still under the care of their parents).

Furthermore, the percent of fledged nestlings that return to breed in subsequent years has declined (Sanz et al. 2003). Pied flycatcher populations that suffer long-term declines in reproductive success and **recruitment** (i.e., addition of new potential breeders to the population) are likely to collapse. In The Netherlands, scientists found that flycatcher populations declined by approximately 90% over 20 years in areas where caterpillar populations peaked early relative to bird breeding activity (Both et al. 2006).

Why are some flycatcher populations able to shift migration and breeding dates when others aren't? There are several mechanisms that could account for this difference, although their relative importance is poorly understood (Pulido 2007). We list just three here. First, flycatcher populations are experiencing different regional patterns of climate change. In areas where spring warming occurs late in the season, caterpillar development is accelerated *after* birds are physiologically committed to breeding. Caterpillars are therefore available for a shorter period of time once chicks have hatched (Sanz et al. 2003). Second, some flycatcher populations breed in areas that experience cold snaps in early spring. When birds breed in cold weather, they have higher metabolic costs and thus less energy to invest in reproduction (Stevenson and Bryant 2000). They also are at increased risk of mortality from extreme spring weather. Therefore, there may be selective pressure against migrating too early (Pulido 2007). Third, migratory birds in poor condition are likely to arrive on breeding grounds late and start breeding late. Both climatic and nonclimatic factors that affect the body condition of birds—such as habitat fragmentation—may be overriding evolutionary changes in the timing of migration and breeding (Pulido 2007).

Figure 8.6



(B)

Changes in (A) breeding success and (B) spring temperature over time in oak forests of central Spain.

Source: Adapted from Sanz, J. J. et al. 2003. *Global change biology*. Oxford, UK: Blackwell Publishing. Modified with permission of Blackwell Publishing.

STUDENT PAGE 8.1

Reporting Form

Names of people in your group:

Data set # (circle one): 1 2 3 4 5 6

Describe the relationship between the two variables in the data set.

Why do you think this relationship exists?

How is this data set related to the main hypothesis? (Circle one answer.)

Supports hypothesis Rejects hypothesis Neither supports nor rejects hypothesis

STUDENT PAGE 8.2

Consensus Form

Names of people in your group:

Pied flycatcher

Data set # (circle one): 1 2 3 4 5 6

Examine the completed Reporting Forms in the envelope. What is the most common interpretation of the data set?

Do you agree with this interpretation? Explain why or why not. (Hint: Think back to other data sets you looked at today.)

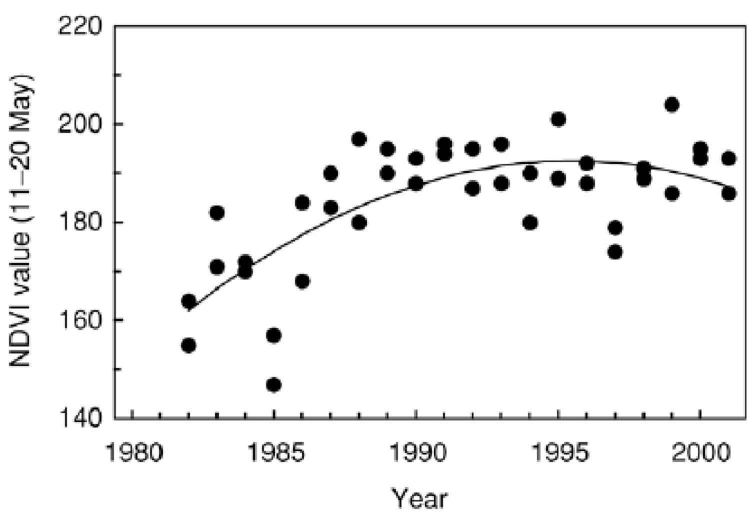
How is this data set related to the main hypothesis? (Circle one answer.)

Supports hypothesis   Rejects hypothesis   Neither supports nor rejects hypothesis

STUDENT PAGE 8.3

Data Sets

DATA SET 1: TIME OF LEAF DEVELOPMENT VS. YEAR IN OAK FORESTS OF CENTRAL SPAIN

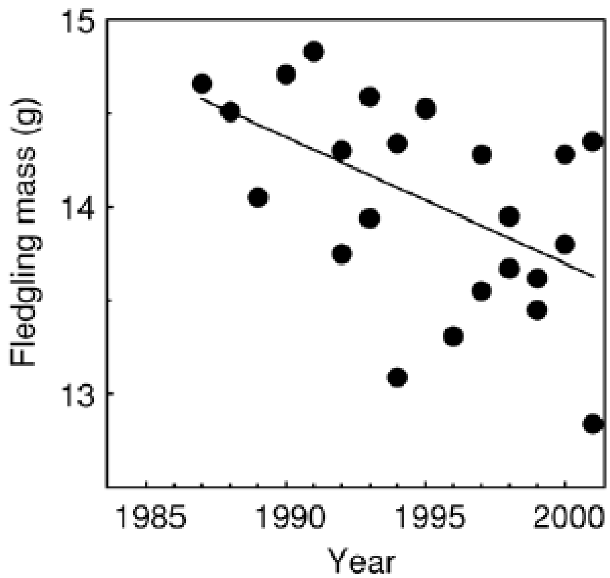


Source: Modified from Sanz, J. J. et al. 2003. *Global change biology*. Oxford, UK: Blackwell Publishing. Modified with permission of Blackwell Publishing.

Helpful hints:

- NDVI (Normalized Difference Vegetation Index) is a measurement of how much photosynthesis is occurring at the Earth's surface. In the spring, it can be used to estimate the *amount of canopy* (forest covering of leaves) that has developed and *when the canopy* developed. If the NDVI is higher in the current year than it was at the same time the previous year, it means leaves emerged earlier in the current year.
- Caterpillars hatch at the same time leaves emerge.
- Some birds may be able to use the amount of canopy as a cue to lay eggs. However, since 1980, flycatchers in central Spain *have been breeding at roughly the same time every year.*

DATA SET 2: MASS OF PIED FLYCATCHER FLEDGLINGS VS. YEAR IN OAK FORESTS OF CENTRAL SPAIN

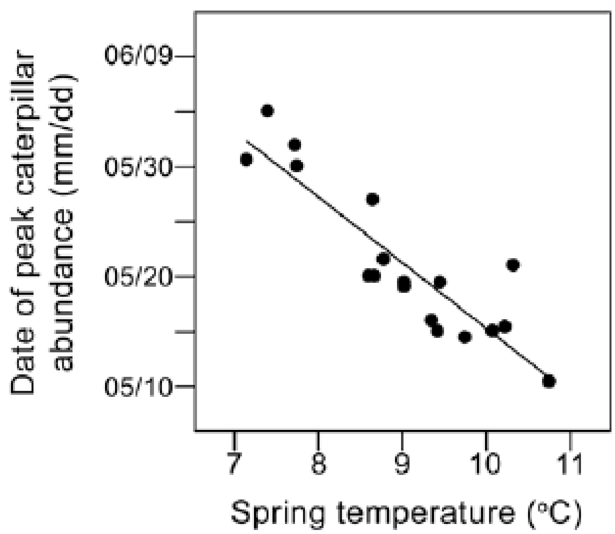


Source: Modified from Sanz, J. J. et al. 2003. *Global change biology*. Oxford, UK: Blackwell Publishing. Modified with permission of Blackwell Publishing.

Helpful hints:

- A **fledgling** is a young bird that can fly but is still under the care of its parents.
- Lighter fledglings are more likely to die than heavier fledglings.
- Light fledglings also may have a hard time migrating south to Africa, where they spend the winter.

DATA SET 3: DATE OF PEAK CATERPILLAR ABUNDANCE VS. TEMPERATURE IN OAK FORESTS OF THE NETHERLANDS



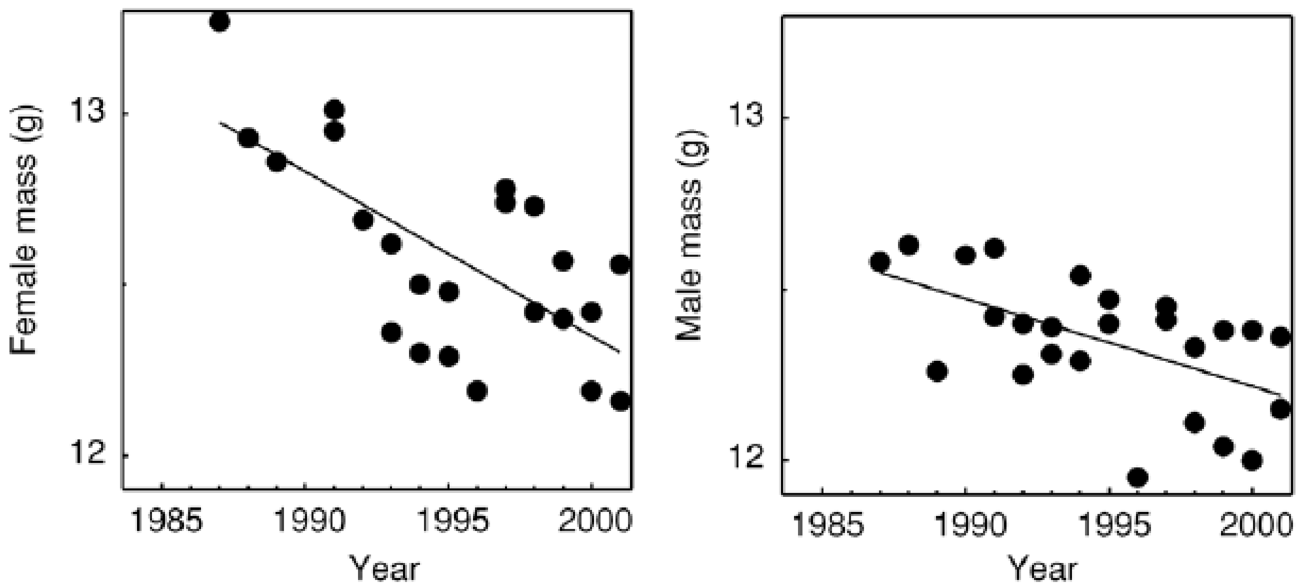
Source: Modified from Visser, M. E. 2006. Shifts in caterpillar biomass phenology due to climate change and its impact on the breeding biology of an insectivorous bird. *Oecologia* 147(1): 164–172. Modified with permission of Blackwell Publishing.

Helpful hints:

- Caterpillars are leaf-eating machines. From the time they hatch from eggs, their main job is to accumulate enough energy to metamorphose into winged adults.
- Caterpillars are ectothermic ("cold-blooded"), like reptiles. The warmer their environment is, the faster they can move around, find food, eat, and grow.
- Some birds may be able to use insect abundance as a cue to lay eggs. However, since 1980, pied flycatchers in central Spain *have been breeding at roughly the same time every year.*

DATA SET 4: MASS OF ADULT PIED FLYCATCHERS VS. YEAR IN OAK FORESTS OF CENTRAL SPAIN

Note: Adults were weighed when their chicks were 12–13 days old.



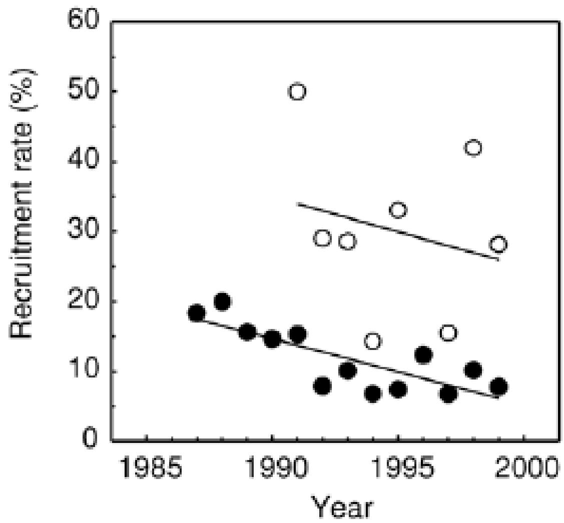
Source: Modified from Sanz, J. J. et al. 2003. ***Global change biology*****. Oxford, UK: Blackwell Publishing. Modified with permission of Blackwell Publishing.**

Helpful hints:

- Adult birds use up a lot of energy when they are taking care of their chicks. If the adults are not getting enough to eat, they will lose weight.
- Males never sit on the eggs, but they help bring food to the chicks when they have hatched.

DATA SET 5: RECRUITMENT RATE OF PIED FLYCATCHERS VS. YEAR IN OAK FORESTS OF CENTRAL SPAIN

Note: The different colored dots are from two different populations of flycatchers.

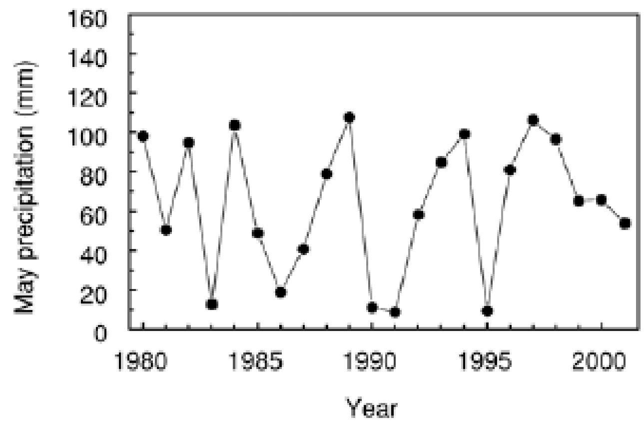


Source: Modified from Sanz, J. J. et al. 2003. *Global change biology*. Oxford, UK: Blackwell Publishing. Modified with permission of Blackwell Publishing.

Helpful hints:

- A **fledgling** is a young bird that can fly but is still under the care of its parents.
- The **recruitment rate** is the percent of fledglings that survive the migration to and from their wintering grounds and return to breed. (Flycatchers usually breed where they were hatched.)
- Fledglings that are in good body condition before they start their first fall migration are more likely to return the following year.

DATA SET 6: SPRING PRECIPITATION VS. YEAR IN OAK FORESTS OF CENTRAL SPAIN



Source: Modified from Sanz, J. J. et al. 2003. *Global change biology*. Oxford, UK: Blackwell Publishing. Modified with permission of Blackwell Publishing.

Helpful hints:

- Small-bodied birds are more likely to die if spring and summer weather is unusually dry and hot or unusually wet and cold.
- Adult birds may not give their chicks enough care in dry and hot conditions.
- Caterpillars may not get enough to eat during extremely dry weather because oak leaves become distasteful and hard to chew. (Imagine someone swapping out your steak for shoe leather!)

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

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.