A Desert

Phenology Lesson

WHEN IS THE GRASS GREENER?

DESCRIPTION

Students will be introduced to phenology (cyclical, seasonal changes in plants) and use data to consider how climate change will impact the phenological cycles of desert grasses and shrubs.

PHENOMENON

Earth's changing climate will affect water availability, resulting in changes to plant phenology, including the green-up, of some plants.

GRADE LEVEL

6-8

OBJECTIVES

Students will:

- Learn how and why scientists monitor plant phenology
- Examine data on green-up dates of shrubs and grasses in the desert
- Model the effects of root length on accessing water
- Predict some impacts of climate change based on phenological patterns in plants

TIME

50 MINUTES

COMMON CORE STATE STANDARDS

English Language Arts

SL.1. Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade-level topics, texts, and issues, building on others' ideas and expressing their own clearly.

RST.3. Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

NEXT GENERATION SCIENCE STANDARDS

MS-LS2-1 Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. *(Clarification Statement: Emphasis is on cause-and-effect relationships between resources and the growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant and scarce resources.)*

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Engaging in Argument from Evidence Constructing Explanations and Designing Solutions	**LS2.A: Interdependent Relationships in Ecosystems** ESS3.C: Human Impacts on Earth Systems	**Cause and Effect** Patterns

BACKGROUND

Phenology is the study of seasonal changes in the life cycles of plants and animals. The development of leaf buds, flowers, fruit, color change, and leaf fall, as well as the timing of animal reproduction and migration, are all examples of phenological events. Temperature, precipitation, and photoperiod (or the seasonal changes in day length) impact the timing of these events.

Because plant development is closely tied to weather and climate, the earth's changing climate will alter the timing of seasonal patterns. For example, plant green-up (appearance of leaves) dates and flowering dates are occurring earlier in the year. Changes in when and how long plants grow and bloom can have a domino effect in ecosystems, impacting pollinators, herbivores, and other animals. You can learn more about phenology and how to collect phenology data as a community scientist from the USA National Phenology Network (https://www.usanpn.org/).

One way to better understand phenological cycles and patterns is to monitor and track vegetation changes over a long period and relate these patterns to environmental cues like temperature, precipitation, and day length. Scientists do this through regular observations and repeat photography of the same

plants over many years. These observations can be done in person or through cameras, like the Phenocam Network (https://phenocam.nau.edu/webcam/).

In the Desert Southwest, plant phenology is largely driven by water availability, but uneven access to groundwater results in two phenological patterns. Shrubs with deep roots are able to take advantage of groundwater reserves that change very slowly. With their near-constant access to water, these plants green-up in a predictable seasonal pattern. Temperature or photoperiod may be the driving factor for when these plants green-up each spring. In contrast, short-rooted plants, including grasses and annual forbs, must rely on precipitation, and they green-up quickly after rainfall. The variable timing of rainfall results in unpredictable green-up times for these plants, and in times of drought, there may be no green-up observed at all.

These two phenological patterns: predictable green-up times for long-rooted plants, and variable green-up times for short-rooted plants, favor the survival of long-rooted plants (typically shrubs) over short-rooted plants (typically grasses) during times of drought. Climate change will increase the intensity and frequency of droughts in the southwest, shifting desert grasslands to desert shrublands, a phenomenon which has been recorded in the 20th century in the Chihuahuan Desert.

MATERIALS

- When is the Grass Greener worksheet (1 per student)
- PowerPoint presentation
- Apple tree phenology cards (one set for every 2-4 students)
- For every 4 students:
  - 2 long straws: approximately 6 inches
  - 2 short straws: approximately 4 inches
  - 4 small bathroom cups with a line drawn approximately 1 cm from the bottom
  - 1 water bottle (if using reusable water bottles, use one with a narrow opening)
- Paper towels
- Timer (if you are not using the counter on slides 12 and 16)

PREPARATION

1. Print one worksheet per student.
2. Set up the slides on the screen.
3. Print and cut the apple tree phenology cards. Prepare one set of cards for every 3-4 students.
4. Cut straws to 6 inches and 4 inches. You will need one straw per student. Half the class should have 4-inch straws, and half the class should have 6-inch straws.
5. Draw a line approximately 1 centimeter from the bottom of each cup with a permanent marker. If the cups are opaque, draw the line on the inside of the cup.

PROCEDURES

INTRODUCTION TO PHENOLOGY (15 MINUTES)

1. **Slide 1**: Introduce the topic of the lesson.
2. **Slide 2:** Put students into groups of 2-4 and give each group a set of apple tree phenology cards with the instructions to put the cards in the order the events happen. Each card represents a phenological stage of an apple tree's annual cycle. Give students 2 minutes to discuss the proper order for their cards.
   a. Correct order: leaf bud, leaf, flower buds, flowers, pollination, fruit
   b. Note that these stages are cyclical, and students could order them to begin at a different stage.
3. **Slide 3:** Show students the correct order and ask students what these cards represent (answers might include seasonal patterns or life cycles).
   a. Note that other plants follow similar patterns; these pictures show milkweed and saguaro cactus as examples.
4. **Slide 4:** Define phenology: the study of these seasonal patterns and cycles in nature.
   a. Point out to students that the events in their cards happen at certain times of year.
   b. People have studied and recorded phenological patterns for thousands of years because the cycles in nature impact many aspects of daily life. Seasonal weather, planting crops or gathering wild plants, hunting seasons, and allergies are all ways that these patterns can impact humans.
   c. The Tohono O'odham people in the Sonoran Desert associate the harvest of Saguaro fruit with preparing for the rain dances and the coming rainy season.
   d. Ask students what phenological events and

changes they notice throughout the year? What phenological changes happen around their birthdays?

5. **Slide 5:** The timing of phenological events is important because many plants rely on other species with their own phenological patterns. For example, pollinators interact with flowers, and some insects lay their eggs on leaves. What would happen if the events and interactions did not line up at the same time? For example, if bumblebees can't pollinate apple flowers, the trees won't produce apples (click forward on the slide). These mismatches would affect many crops we rely on. The scientific term for this is phenological mismatch.
6. **Slide 6:** The timing of phenological events is controlled by factors like temperature, precipitation and day length. Climate change is expected to impact these factors and lead to phenological mismatches. Changes in phenology can have a domino effect in ecosystems. Today, we are going to investigate the phenological patterns of four desert plants, specifically when they green up, or sprout their first leaves of the year. We will think about how climate change will impact their phenology and the ecosystem.

ANALYZE PHENOLOGICAL DATA (10 MINUTES)

1. **Slide 7:** To monitor plant phenology, scientists must observe when plants are going through phases like growing leaves, blooming, or losing leaves. They can do this by directly observing plants. Many scientists also use Phenocams, which are web-connected cameras that take pictures at regular intervals. A computer program can then analyze the greenness of each pixel and graph the data. You can see the annual cycles in greenness in the graph on the slide. Dr. Dawn Browning is a researcher at the USDA's Jornada Experimental Range and uses both methods to collect phenology data.
2. **Slide 8:** Since 1993, Dr. Browning and other scientists have been observing plant phenology in the Chihuahuan Desert in Las Cruces, New Mexico. They go out every month and record what month green leaves first appeared on individual plants. These graphs show how many plants were observed greening-up in each month of the year. Support students in reading these graphs and have them answer questions 1 and 2 on their worksheet.
    a. Phenological pattern of honey mesquite bush: Most plants green up in April. It is a fairly predictable pattern.
    b. Phenological pattern of tarbush: Green up almost always happens in January. It is a fairly predictable pattern.
    c. Phenological pattern of black grama grass: Green up most commonly happens in March, but also in January. Most plants green up in the spring, but the green-up dates are more variable than in honey mesquite or tarbush.
    d. Phenological pattern of ear muhly grass: Green up most commonly happens in January, but is also common in February, March, and April. Green-up dates are quite variable, and there is another small peak in July. Green up generally happens in the spring.
    e. What could be the cause of these phenological patterns? Temperature, precipitation, sunlight, and day length are most likely causes.
    f. Have students discuss and answer question 2 on their worksheet: What is the difference between the phenology of the bushes (honey mesquite bush and tarbush) and the grasses (black grama grass and ear muhly grass)? [The bushes both have very predictable phenological patterns. The grasses are much more variable in their timing.]
3. **Slide 9:** Show students the root diagrams and discuss what they observe. Note that the two long-rooted shrubs (honey mesquite and tarbush) have more predictable phenology, and the two short-rooted plants (black grama grass and ear muhly) have more variety in their phenology. Remind students that roots are very important in getting water to plants.
    a. Dr. Browning has a hypothesis that root length plays a large role in plant phenology.

MODELING PHENOLOGY OF DESERT PLANTS (10 MINUTES)

1. **Slide 10:** We will play a game to try to model and understand how root length might affect phenology. In our model, a water bottle will represent groundwater, a straw will represent the plant roots, and a cup will represent the main body of the plant. Time will be an important part of our model too.
2. **Slide 11:** Put students in groups of 3 or 4. Give each group a water bottle, 2 long straws and 2 short straws, and a cup for each student. Each student will use 1 straw.
    a. The goal for each student is to fill their cup to the line using their straw and finger. Students will do this by inserting the straw into the water bottle and placing their finger on top of the straw, then moving the straw over their cup and releasing their finger. Students are NOT putting their mouth on the straw.
    b. Rules: don't tip or squeeze the water bottle to get the water higher. If you can't reach the water, you can't reach.
    c. Students should clear their desks, as they will get wet. Consider putting a towel, paper towel or tray on the table.
    d. Give students 30 seconds to practice moving water with the straw, then return water to the bottle

before the game begins.

e. Students should place the water bottle in the middle of the table where everyone in their group can reach it. **It is a good idea for one student to hold the base of the water bottle to keep it from falling over.**
f. The game begins when you click forward in the slide show and the slide says "Go!".
g. When the game begins, students use their straws and fingers to get water out of the bottle and into their cup. When they fill their cup, they must look up at the screen and make a note of what number is showing on the screen.

3. **Slide 12:** Start the game by clicking forward on the slide you will see the words "Ready, Set, Go!" flash on to the screen. Then the numbers will automatically advance until they reach 25. Numbers advance every 5 seconds.
   a. If the water level drops below the reach of the short-rooted plants, those plants will remain dormant (no green-up) that year.
   b. If you cannot use the counter in the slides, use a timer to count seconds. Have students note how many seconds it took to fill their cup, divide that time by 5 (to make it equivalent to the timer in the slides), and round to the closest whole number. Use that number when recording data in the data table.
4. **Slide 13:** Create two graphs of the class data on the board, using the template in Fig 1. Create one graph for long-rooted bushes, one graph for short-rooted grasses and have students report the number that was showing when they filled their cup on the appropriate graph.

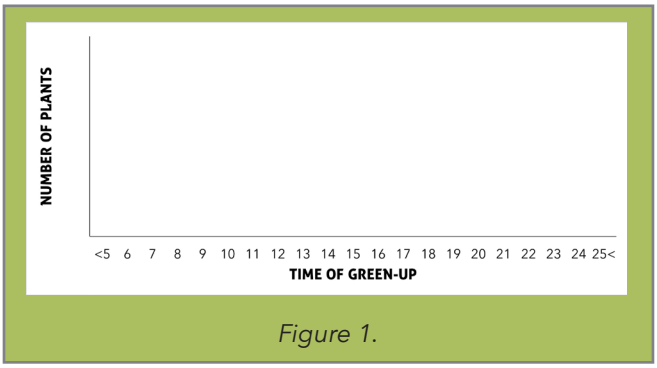

Figure 1.

   a. Compare your graphs for long-rooted bushes and short-rooted grasses to the four phenology graphs on page 1 of students' worksheets. Discuss the importance of water availability on the green-up timing plants.
5. **Slide 14:** Ask students why long-rooted bushes are able to green up at about the same time every year. [It is because they have access to a reliable source of deeper groundwater.] If we had a lot of rain, would the short-rooted grasses have greened up earlier? [Yes, if there is more water in the top layer of soil where grass roots grow, those plants can green up earlier.]
6. Have students answer questions 3 and 4 on their worksheet.

APPLYING PHENOLOGY KNOWLEDGE AND SOLVING PROBLEMS (10 MIN)

1. **Slide 15:** Climate change is predicted to change when rain falls, how much rain falls, and how much and how fast water evaporates in the southwest. Discuss with students how that will impact both long-rooted bushes and short-rooted grasses.
2. Give students time to discuss with their group and answer question 5: Read the scenarios below and apply what you know about phenology, climate change, and desert plants to predict how each person will be affected by climate change. If time allows, have students share and discuss their answers as a class.
3. Scenarios:
   a. Freddy is a rancher whose cows graze on desert grasses. If there isn't enough grass, Freddy must bring in hay or supplemental food to ensure his cows stay healthy. Based on what you know about the phenology of grasses, how will Freddy be impacted by climate change? How can Freddy adapt to climate change or solve the problem it is causing?
   b. Mariana walks to school every day. Next to the school is a large area with no buildings. On windy days, lots of dust is picked up off the ground from this area and gets in her eyes, mouth, and hair. Mariana has noticed that when grass is growing, there is less bare ground and the grass seems to hold onto the soil. Based on what you know about the phenology, how will Mariana's walk to school be impacted by climate change? How can Mariana adapt to climate change or solve the problem it is causing?

MODELING CLIMATE CHANGE CONDITIONS

1. **Slide 16:** If time allows, you can use the game to model climate change conditions.
   a. Refill most groups' water bottles. Select two or three groups to represent drought conditions, and do not refill their water bottles. Ensure drought groups have enough water that the short roots will be able to reach it at first, but it's ok if they struggle to fill their cups.
   b. The teacher (or assign 1 or 2 students to this task) will represent rain by adding water to each group's bottle during the game. Groups will receive different amounts of water at different times (random), creating more variability in the results

for short-rooted grasses, but having less impact on long-rooted bushes.

2. **Slide 17:** Add your results from this round to the same graphs you used in round one. Use a different color for round two data.
   a. Compare your graphs for long and short-rooted plants and discuss the impact of climate change on each.
   b. Note that short-rooted grasses are more reliant on rain because they can't reach as much groundwater as long-rooted plants, so changes in rain have a larger impact on grasses.
   c. Can students use this knowledge to predict when each plant will green up next year?

EXTENSIONS

1. Let students explore phenology data and images on the PhenoCam website (https://phenocam.nau.edu/webcam/). Ask students to pick a site that interests them and use the pictures and data to describe the phenological patterns of that site and hypothesize what environmental factors influence those patterns (i.e., temperature, rain, sunlight, day length). Then ask students to predict how climate change could impact those factors and the phenological patterns.
2. Mini Data Jam: Have students summarize one of the data trends shown on one of graphs from the lesson or from the PhenoCam website. Then challenge them to complete a Mini Data Jam based on the instructions in this video.