

# Flowering Phenology: How do plants know when to flower?

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**Time:** 2-3 days

## **Goals:**

To develop a basic understanding of what biotic and abiotic factors affect plant reproduction (via flowering), how human activities may affect plant reproduction (via affects on flowering), and the potential consequences for humans, plant population dynamics, and community dynamics.

## **Objectives:**

The number of objectives addressed depends on the academic level of the students.

Students will be able to:

1. Define (flowering) phenology.
2. Describe what environmental factors are known to affect flowering phenology and how they affect the timing of flowering.
3. Describe how the interaction of environmental factors and flowering phenology affects plant reproduction, survival, and interactions with other organisms (including animals, micro-organisms, and other plants).
4. Make predictions about how changes in environmental conditions may affect flowering phenology and the consequences.
5. Discuss how urbanization affects flowering phenology, the potential consequences, and possible solutions to some of the consequences.

**Grade Level:** 7<sup>th</sup> grade to high school

## **State Standards:**

The following standards are explicitly addressed in this lesson. Additional standards can be reviewed (strongly encouraged) or met during the execution of this lesson.

SC03-S4C3-05: Describe how environmental factors in the ecosystem may affect a member organism's ability to reproduce.

SC07-S4C3-03: Analyze the interactions of living organisms with their ecosystem (e.g. limiting factors).

SC07-S4C3-05: Predict how environmental factors affect survival rates in living organisms.

SCHS-S4C3-02: Describe how organisms are influenced by a particular combination of biotic and abiotic factors in an environment.

SC08-S4C4-04: Compare the symbiotic and competitive relationships of organisms within an ecosystem (e.g. native vs. non-native).

SC08-S4C4-06: Describe the factors related to pollination that allow for the survival of organisms.

SCHS-S4C4-04: Predict how a change in an environmental factor can affect the number and diversity of species in an ecosystem.

SC07-S3C1-01: Analyze environmental risks caused by human interactions with biological systems.

SC07-S3C1-03: Propose possible solutions to address the environmental risks in biological systems.

SCHS-S3C1-04: Evaluate the factors related to urban development that affect the quality of the environment.

**Lesson:**

This lesson teaches about environmental influences on flowering phenology. Presented below is a brief summary of what is known regarding environmental effects on flowering phenology. However, it must be kept in mind for both the instructor and the students that while environmental responses are generally well known, quite a bit of mystery remains regarding the mechanisms. This presents a great opportunity to reiterate there is still much for science to discover about the workings of nature. This lesson should be part of a unit that includes learning about natural selection, plant parts, pollinators, and general ecological principals. The depth of information presented to students depends on their academic level. Information about the influence of urbanization on flowering phenology is also provided to allow incorporation of urban ecology.

**Background:**

Phenology is the timing of biological events such as growth and reproduction. Genes and their interaction with the environment determine the timing and duration of these events. Environmental influences on the timing of growth and reproduction events allow organisms flexibility to adjust to spatially and temporally variable environments. Temperature, moisture, and photoperiod are three known important triggers for both animals (e.g. arthropods) and plants. Understanding phenology is complicated by the fact that the event that triggers flower development may occur months to a year before one sees flowers and that multiple triggers may interact (e.g. temperature and photoperiod; moisture and temperature).

**Temperature.** Biochemical reactions speed up as temperature increases. This also appears to apply to the biochemical reactions involved in flowering phenology. Research conducted in temperate, boreal, and mediterranean areas indicate the plants that respond to temperature increases can sense and sum temperature. Scientists refer to this summing as finding the degree-days. They hypothesize that using degree-days instead of one set temperature "helps" the plant avoid early or late flowering due to unseasonable cold or warm weather. Also, it is generally agreed that the perception of temperature interacts with the perception of photoperiod to begin the biochemical reactions of flower (and leaf) production. Ephemerals (herbaceous plants living less than two years) that bloom in early spring and animal pollinated plants in temperate, boreal, and mediterranean regions tend to be strongly influenced by temperature. Woody perennials and wind pollinated plants tend to be less influenced, but still affected, by temperature. Temperature increases associated with global warming and urbanization (urban heat island) are thought to be the cause of earlier blooming occurring in the United States, Europe, and Asia (the places most studied). Higher temperatures are also hypothesized to be the main driver behind the earlier start and increased severity of allergy season (pollinosis). A chilling period (< 15 °C) before a temperature increase (winter) is also known to be necessary for some plants to begin flowering (and leaf production). One

researcher found that a decrease in time spent in the chilling period increases the degree-days necessary to begin flowering for some plants. This may have implications for the effects of global warming and urbanization associated temperature increases.

**Photoperiod.** Photoperiod refers to day-length—or, more accurately, night-length since the leaves of plants can sense and measure dark periods (night) rather than light. Not all plants respond to photoperiod. Temperate and sub-tropical plants are generally more sensitive than others, such as tropical plants. Scientists hypothesize this is because temperate and sub-tropical regions have distinct seasons that can be predicted by photoperiod. Moreover, many crop plants are bred to be insensitive to photoperiod to widen their planting season and number of places to plant the crops. Plants sensitive to photoperiod appear to use red and far-red light to initiate communication to other cells to begin flower production. Scientists hypothesize that a hormone, still unidentified, is the key “communicator.” Research shows that exposure to as little as 1 minute of low wattage incandescent light bulbs can affect photoperiod perception by plants—and decrease growth and reproduction. While light pollution has been studied in association with human health problems (circadian rhythms), animal health and fitness, and problems with star gazing, no research has been conducted regarding possible perceived photoperiod changes associated with urbanization and its affects on flowering phenology.

**Moisture.** Not much research has been done on the importance of moisture; however, the few studies conducted in arid, semi-arid, and dry tropical regions indicate that moisture is a dominant trigger for these plants. These studies indicate that precipitation from the previous wet season is important in triggering flowering (as well as fruiting and leafing in some cases). Like temperature, water is essential for biochemical reactions. No studies had been found at the time of this writing regarding urbanization effects, moisture availability, and their effect on flowering phenology. However, in urban arid areas such as the Phoenix metropolitan area, more water is probably available more consistently across years.

**Natural Selection.** The abiotic factors discussed above are important selective forces for plants because if plants flower at the wrong time of year they risk unsuccessful reproduction and wasted resources. This could be due to lack of moisture (during the summer) or too low of temperatures (during the winter). Plants that flower too late or too early for optimum environmental conditions risk producing less offspring and, therefore, not spreading their genes as well as those plants that flower during optimum environmental conditions. Common ragweed, for example, is not as much of a problem in Winnipeg, Canada as it is for more southern regions because its critical day-length (length of night that initiates flower production) does not occur until mid-August. By this time, ragweed plants do not have enough time to flower and produce seeds before winter arrives and kills the plants. Abiotic factors are not the only selective forces on flowering phenology. Biotic forces also have a role. Pollinators, pests, and pathogens can provide selective pressures. Pollinators, for instance, are necessary for many plants to obtain genes from other individuals via the transfer of pollen. If plants that require pollinators flower when the pollinators are not available, they will not produce offspring and waste resources on reproductive organs. Plants that can self-pollinate may be less influenced by animal pollinators than others that require out-crossing. Moreover, inter-specific and intra-specific synchronous or asynchronous flowering may be selected for under

different conditions. For example, to ensure out-crossing, male and female flowers on plants may flower at different times. Also, to reduce the chances of pollen from other species clogging the stigma and preventing successful pollination, asynchronous flowering may be selected for. On the other hand, environmental conditions may limit the time frame available for successful reproduction due to limited resources (e.g., pollinators, water, warmth, sunlight energy) and select for synchronous flowering. Finally, pathogens and pests that feed upon flowers can also exert selective pressures.

**Humans and urbanization.** More than 50% of the world's population lives in cities. These urban ecosystems differ from other ecosystems in that they are dominated by people, their activities, and their structures. Humans change ecosystem function and structure. In temperate regions, cities tend to be warmer than the surrounding environment. In desert regions, like Phoenix, Arizona, the city tends to be cooler than the surrounding native habitat. Although, microclimate is highly dependent on land-use (e.g., watered lawns are cooler than asphalt or sandy desert ground). Also, in desert cities, people increase the water available (may lead to cooler temperatures in Phoenix). It is possible for less water to be available in any part of the world due to ground water pumping, surface water use, and drought. Finally, the lighting and pollution in cities may affect a plant's perception of photoperiod. All of these factors, plus more, can affect flowering phenology. This, in turn, can affect community dynamics. Therefore, it is important to study how urbanization affects a variety of native and non-native plants in different environments and the potential consequences. This information can then be used in management of pests, pathogens, plants, pollinators, and other consequences.

**Materials:**

- Index cards
- Small pieces of wrapped candy
- Post-it notes or "sticky" felt (multicolored—white, yellow, blue, red, green)
- Poster board (onto which you glue cups) (or large sheets of paper)
- Plastic cups (white/clear, yellow, blue, red, and green)
- Markers, pens, etc
- Tape, glue, string, stapler, staples

**Preparation:**

Plant Construction Options:

1. Attach two pieces of poster board together, sandwich-board style, for each student that will be a plant. Attach cups of one color to both boards. Place some candy pieces in the cups.
2. Use a bucket (rather than the cups) and hang from students' neck. Place some candy pieces in the bucket.

3. Place cups on table/desk where student will sit on the desk. Place some candy pieces in the cups.

**Cards:**

1. Write each color and set of months listed below on five index cards each. There should be a total of 80 cards. Divide them into four piles, one for each category listed.

**Plants:**

Flower Color

White

Yellow

Red

Green

Months Offering Food

Feb, March, April

March, Aug,

September

July, August

April, May

**Animals:**

Attraction Color

White

Yellow and Red

White and Yellow

Months looking for Food

Feb, March, April

September, October

March, August

June, July, August

March, April

**Lesson:**

**Part I: Introductory Activity (~1 day)**

1. Split the class into two groups. One group will be the plant group and the other group will be the animal group. Have each student from the plant group draw one card each from their flower color cards and their month cards. Have each student from the animal group draw one card each from their attraction cards and their month cards, as well.

2. Tell the plant group, without the other group present, that their goal is to produce offspring. However, since they are grown plants and cannot move, they need to attract an animal, give it pollen (stick pollen (e.g., Post-It notes) on the animals while they are collecting food), get the animal to go to another plant of the same species, and collect pollen from other plants of the same species. The plants need to do all of this without saying anything to the animals and without moving around (except for arms and hands to transfer pollen). The only way they have of attracting the animals is by showing colors and offering food. Also, they can only offer food during specific times of the year. Tell the animal group, without the other group present, that their goal is to obtain as much food as possible (for their own and their family's survival) and they need to collect their food from plants. They will know a plant may have food available by being attracted to specific colors (from their card). Also, they can only collect food during certain times of the year. The students

who draw the green card for flower color need to use air/wind to transfer their pollen—they do not need animals.

3. Give the plants their pollen and food (the amount in the cups should vary from zero to many pieces) they will have available for the animals and have them pick a spot in the classroom to “take root.” Tell the students that you, the teacher, will call out the months of the year, each of which will last thirty seconds. If it is a month that is not designated as their food offering time or food collecting time, they have to immediately sit down. If the month called out is one in which they offer or collect food then they stand up and follow the instructions given earlier to them. This activity should work out so that some plants cannot reproduce at all or much less than others for reasons such as: other plants of the same species not flowering at the same time, little overlap in flowering time, other species not around, pollinators not present, pollinators not going to other species, etc. Also, the animals should vary in how much food they obtain for reasons such as: not all flowers have food; flowers have very little food; the plants from which they seek food are not available; the plants from which they seek food are available for short periods of time, etc.

4. At the end of the year, the plants figure out how many offspring they are able to produce and the animals figure out how much food they were able to collect by filling in their worksheets and writing their numbers up on the board. They then answer the questions on their handout on their own. To answer the questions, the students need to not only think about their results but also about the conditions that possibly lead to their results. Getting the “correct” answers is not important at this time. The purpose of the worksheets is to twofold: (1) obtain a preliminary assessment of what the students know and (2) get the students thinking. The worksheet grade should be based on the students answering all of the questions and the answers demonstrating critical thinking—not on if the answers are “correct.”

## Part II: Discussion

1. The offspring production information, food collection, and answers to the questions are discussed as a class by incorporating them into the “lecture”. Present information to students in an interactive manner by discussing how their information compares to research by scientists. Adjust the depth of the information to the appropriate level for the class. For example, a high school class can learn what scientists know about the mechanism of photoperiod perception. The important points to get across (at any academic level) are: the three known dominant flowering triggers; how natural selection by biotic and abiotic forces can produce the current phenological behavior; how changing environmental conditions may affect flowering phenology; the consequences of changing flowering phenology on a plant's fitness, a plant population, and community dynamics (e.g. pollinators, people, pests, herbivores). The particular case of urbanization effects on flowering phenology should be discussed with the students, despite the paucity of available information, since they all can relate to the urban ecosystem.

**Evaluation:**

The students are evaluated based on their participation in classroom activities and discussions (~40%), their worksheet (~20%), and an exam (~40%). A report and/or a presentation may also be included in addition to, or instead of, the exam. The exam should include multiple choice questions, short-answer questions, and an essay question to allow students a variety of ways to demonstrate what they have learned.

**Extensions:**

1. Have students research a plant species: finding out its flowering phenology, important animal interactions with its flowers, nectar/pollen, seeds/fruits, etc., social importance, economic importance, and other interesting information. Present the plant information in a written report and/or in a presentation (PowerPoint or poster).
2. Have students follow the protocol for tracking phenology of the plants around the school (and at home, if desired).