# Wildflower Phenology: A Case Study

Phenological Responses to a Changing Climate

## [Link to the visualization](https://huckley.shinyapps.io/PlantPhenology/)

## [Link to TrEnCh-Ed](https://trench-ed.github.io/#)

## Objectives

* Describe changes in temperature over time.
* Analyze the impacts of climate on wildflower phenology.
* Test hypotheses about how the timing of flowering responds to temperature and propose potential mechanisms.
* Consider the ecosystem implications of phenology.

## Core Concepts -- *BioCore*

* Physiology: Evolution
* Physiology: Systems
* Ecology & Evolutionary Biology: Systems

## Instructions

### Background

1. Define phenology.
2. Other than the first flowering date, what are three phenological events for plants?
3. Why is flowering an important phenological event?

### Temperature and First Flowering Date

The app includes a figure that will allow you to look at changes in temperature over a period of 122 years (1893-2015). There is a lot of natural variability in the data (i.e. differences between individual years), so to help you see broad long term patterns, look at the blue trendline instead of the scattered data points. Answer the following questions:

1. Keeping the range of years from 1893 to 2015, select four different months and watch how the graph changes. The months you select should be months you consider to be representative of each of the four seasons: winter, spring, summer, and fall.
   1. Why is the y-axis different in each of the four months you selected?
   2. How does the x-axis change between the four months?
   3. In which month was the slope of the blue trendline the steepest? Interpret this result by describing the relationship with temperature over time.
   4. In which month was the p-value the largest? Interpret this result by describing the relationship with temperature over time.
2. Plot annual average temperatures (find this at the bottom of the list of months) across the entire time period.
   1. Around how much has the average annual temperature increased since the 1890s?
   2. If the current trend continues, what will the average annual temperature in Concord be in 2075?
3. The timing of flowering is highly dependent on temperature. Hypothesize which months are likely to have the largest effect on flowering phenology and explain your reasoning.

### Relationships between temperature and First Flowering Date (FFD)

1. Create scatterplots for all species, showing annual temperature on the x-axis.
   1. For which two species does phenology advance with warming (you see a clear negative slope)?
   2. What do these species have in common?
2. Create scatterplots for all species, showing January-April temperature on the x-axis.
   1. Now, which species have flowering phenologies that advance with warming?
   2. Keeping in mind the months that warmed the most over the years, what can we conclude about the flowering dates?
3. Propose a hypothesis for why some species show higher or lower slopes when you plot FFD against temperature. (There are many possibilities!)

### Synthesis

1. What impacts could changing FFD’s have on other species (including animals) in the ecosystem?
2. How could the data used in this study be improved? What other sources of data can be used to study changes in phenology or abundance of species over time?