Fall Colors, Temperature, and Day Length

Students use internet data to explore the relationship between seasonal patterns and climate

Stephen Burton, Heather Miller, and Carrie Roossinck

Along with the bright hues of orange, red, and yellow, the season of fall represents significant changes, such as day length and temperature. These changes provide excellent opportunities for students to use science process skills to examine how abiotic factors such as weather and temperature impact organisms. The activity described in this article uses available internet data to encourage students to explore the relationship between seasonal patterns and climate (plant phenology) as well as day-length data. In particular, students develop and test hypotheses to explain latitudinal differences in leaf-color change.

SCILINKS
THE WORLD'S A CLICK AWAY
Keywords: Autumn leaves
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Enter code: TST090701

Identifying patterns

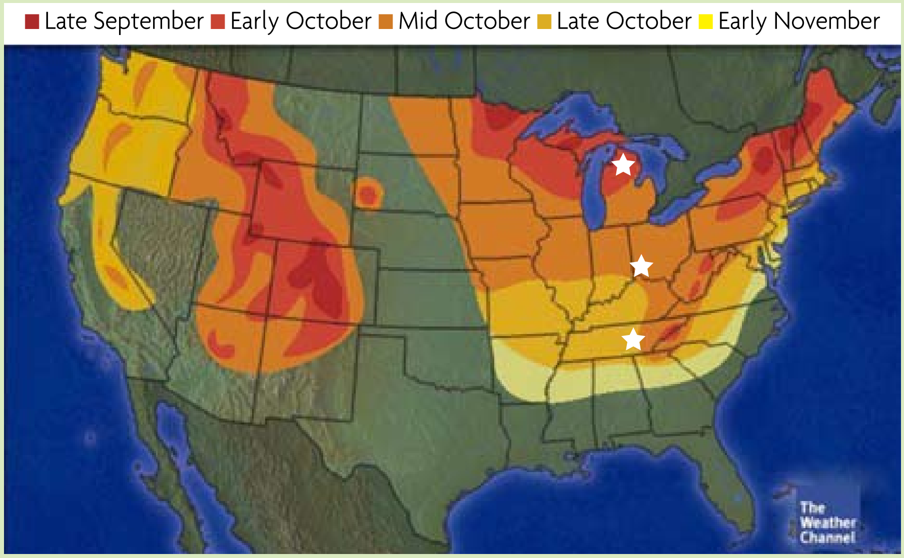
To engage students, we begin the lesson by asking them to examine the normal peak times of fall color across North America using a map (Figure 1) reproduced from The Weather Channel's website (see "Resources" at the end of this article). As a class, students make observations and describe patterns. Students easily notice that colors in the Midwest follow a latitudinal gradient. Students also observe that the latitudinal gradient does not always seem to hold true over mountainous regions, and entire regions of the United States show no evidence of color change.

Students are then asked to suggest possible explanations for the observed patterns. In particular, we ask students to focus on the latitudinal variation in peak color. Students often offer temperature differences as the potential explanation for earlier peak color in northern areas. This lesson occurs well into the semester when students are already familiar with scientific inquiry, which allows us to reinforce the idea that their explanations are potential hypotheses that can and should be tested. Students are keenly aware, from previous discussions, that scientists are never satisfied with just generating hypotheses. Students understand that a possible explanation requires evidence to determine its validity. Therefore, we challenge students (usually working in groups of three to four) to design experiments to provide evidence to refute or support their hypotheses.

FIGURE 1

Normal peak times for fall color.

Normal peak times for fall color as identified on The Weather Channel website.



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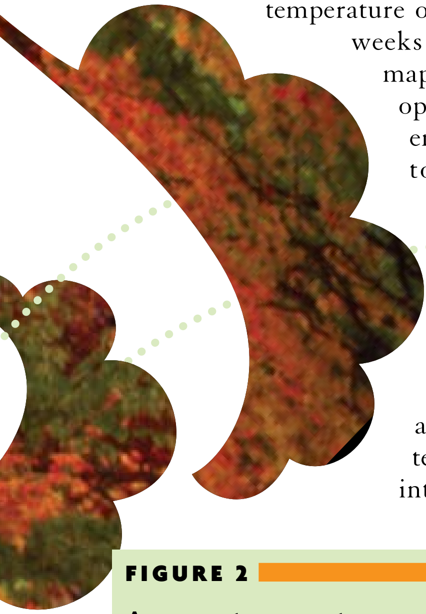
Testing the temperature explanation

As students begin to discuss possible methods for testing suggested explanations (hypotheses), it becomes clear that the first step is to determine if latitudinal differences result in temperature differences. Students are encouraged to design experiments in which they select single cities at different latitudes in each of the peak color time regions and investigate temperature differences among them. For example, students often predict that cities at higher latitudes should be cooler.

Once the design has been established, we present students with data collected via the internet from three cities (shown as stars on Figure 1) at different latitudes. The data results support the hypothesis that temperature differences may explain the differences in peak times (Figure 2). However, we help students examine the issue of small sample size and a fair test and discuss the need for more data points. To address this shortfall, we ask each group to collect data on one to three additional cities within the region being investigated. With each group collecting data on a few cities at different peak times, it is possible to amass a dataset large enough to evaluate the results. Of course, students are interested in finding out how we are going to collect this type of weather data on such short notice.

Current and past weather data for most U.S. locations are now easily accessible through the internet. One of our favorite websites that contains appropriate data is Weather Underground (see "Resources"). This website provides a vast array of weather-related data that can be used to answer a variety of questions connecting weather and biological phenomena. The weather data is reported from airports within the region. Selecting a particular city identified on a map that does not have an airport defaults to the nearest airport automatically. A key feature in collecting data is the identification of cities around the same latitude. Because cities along the edge of the peak times may overlap in temperature, we encourage students to find cities at the middle of the peak time band shown in Figure 1. A great way to help students select locations is to provide an atlas of

North America showing major cities. (**Note:** Students can also use Google Earth to locate cities and towns, and obtain data for elevation, latitude, and longitude [see "Resources"].)To minimize problems of altitudinal variation, a teacher could also provide a list of cities at different latitudes with similar altitudes and allow students to select from the list. To prevent overlap, the teacher can list the cities selected on the board.



As students begin the data collection process, we encourage them to focus on the mean temperature of each location for the peak weeks identified on the original map (Figure 1). This is a great opportunity to reinforce scientific inquiry skills required to appropriately evaluate hypotheses. In particular, we ask students to determine if using the temperature from one year as a comparison is a fair test. Students often realize that averaging across multiple years is a better test as it potentially takes into consideration variability that might occur across multiple years. Fortunately, the Weather Underground website provides access to archived weather data allowing students to collect data from multiple years.

As students examine the data, they find that their results corroborate the original results showing that cities at higher latitudes (and thus earlier peak color times) are cooler during the fall (Figure 2). Students are often satisfied with the conclusion that temperature plays a significant role in leaf-color change. We encourage students to consider other correlations and alternative hypotheses to determine if there are other possible explanations.

Considering other variables

To reinforce the tentative nature of science, we give students a graph showing that day length (more correctly, length of darkness) is also greater in a city with an earlier peak color zone (Figure 3, p. 34). This would suggest that leaf-color change may be influenced by length of darkness in a day as well. Students are challenged to consider what variable—temperature or daylight hours—would explain the date of peak color.

Many students are quick to point out that the amount of daylight could potentially influence temper-

FIGURE 2

Average temperature versus date.

Average temperature is consistently higher at lower latitudes (Columbia, TN) compared to higher latitudes (Traverse City, MI). The peak leaf color time differences seem to correspond with lower temperatures.

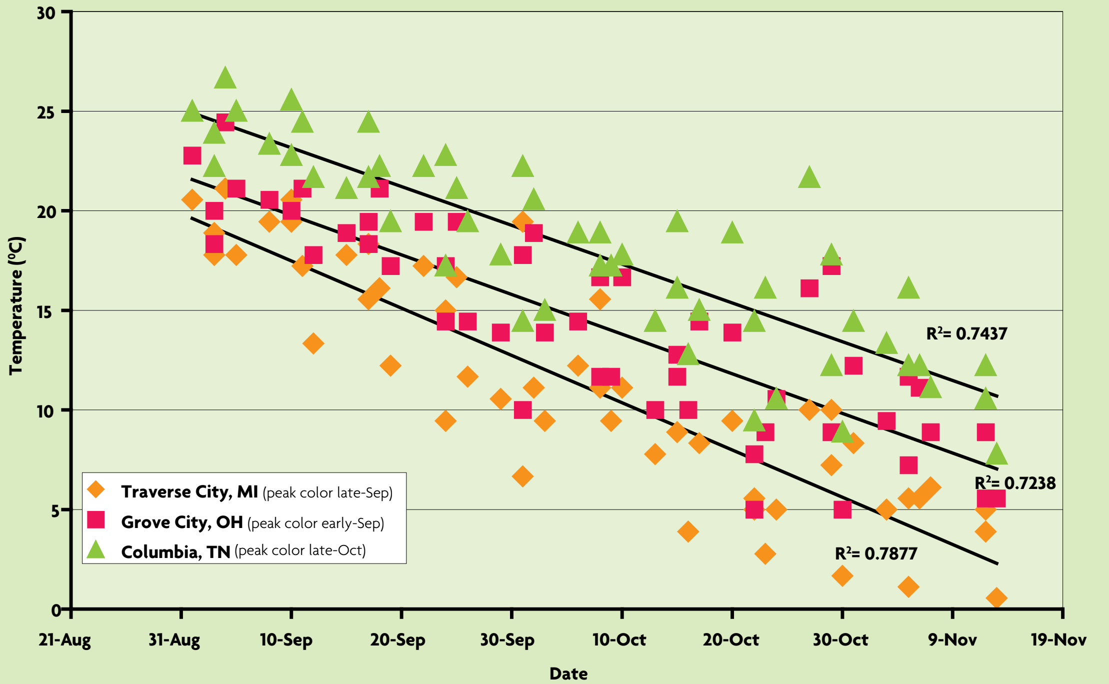
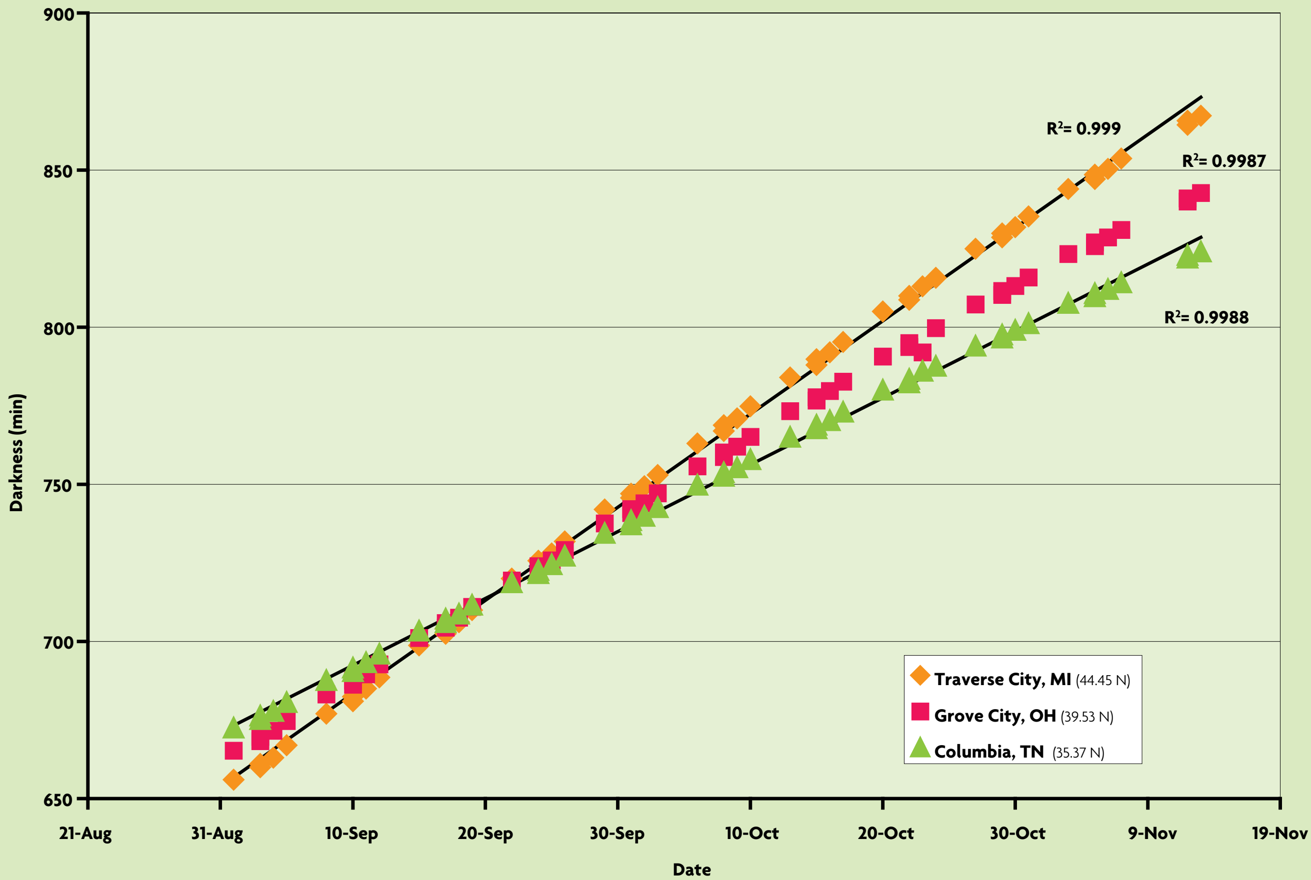


FIGURE 3

Average darkness versus date.

Daily darkness is consistently greater at higher latitudes (Traverse City, MI) compared to lower latitudes (Columbia, TN). The peak leaf color time differences seem to correspond with more darkness.



ature. Students are then asked to test this hypothesis by graphing the temperature of the peak time with day length (Figure 4). Day length is available at the Weather Underground website but also can be obtained for almost any location and year at the U.S. Naval Observatory website (see "Resources"). As students collect their data, we try to reinforce the idea that date and day length are highly correlated. Further, our calendar is set around changing day lengths so correlations between temperature and day length are not surprising but certainly confounding for our study.

Controlling variables

How do we eliminate day length and focus on temperature? Controlling for day length is a challenge for students. We encourage students to go back to the original map (Figure 1, p. 32) and identify areas with different peak times but where it is unlikely day length would be different. For instance, we have students take a closer look at Virginia using a figure from the University of Virginia Climatology Office (Figure 5), which shows that the peak times follow an east-to-west pattern where there is no difference in daylight hours (2006).

After students have identified regions showing longitudinal differences, we show students Figure 6 (p. 36) which provides evidence that suggests a relationship between peak time and temperature. Again, we encourage students to collect more locations to increase sample size. Not

FIGURE 4

Average temperature versus darkness.

Daily darkness is consistently greater at higher latitudes (Traverse City, MI) compared to lower latitudes (Columbia, TN). The peak time seems to correspond with more darkness.

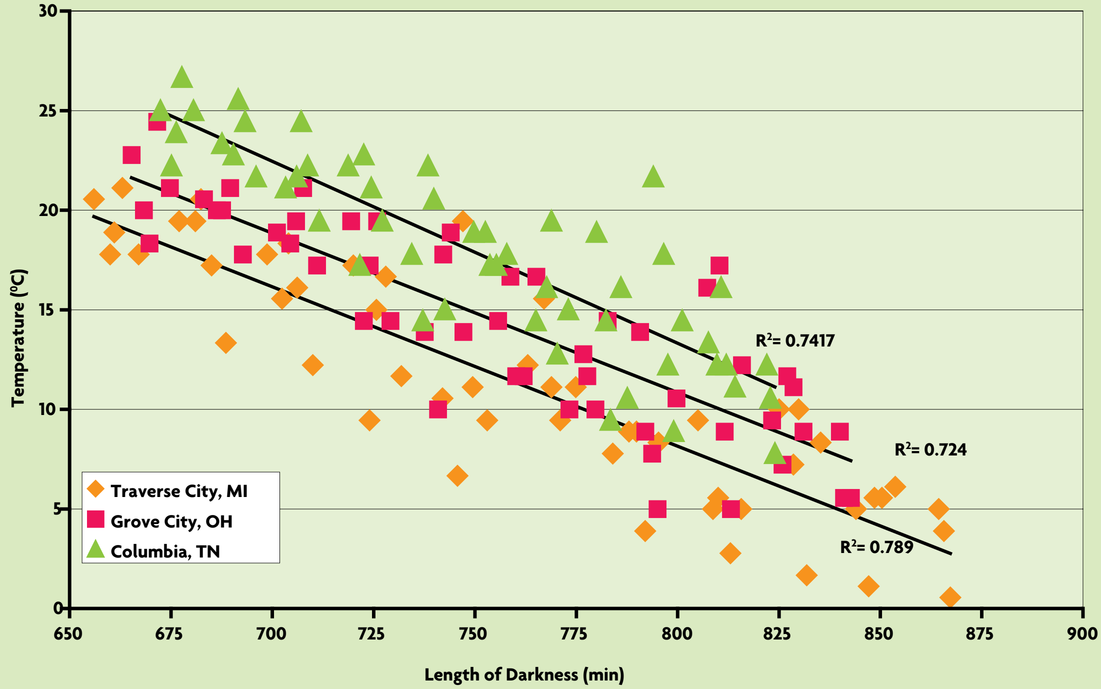
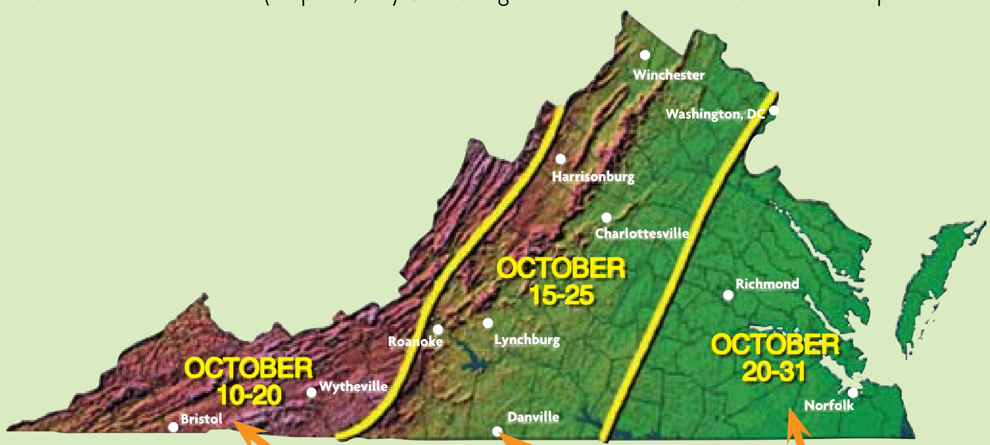


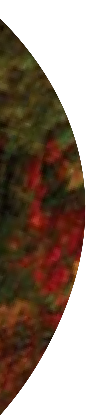
FIGURE 5

Map of Virginia showing peak leaf color dates.

Sites selected for comparison were at the same latitude, but varied only by elevation. Higher elevations (Abingdon, VA) appear to reach peak color before lower elevations (Emporia, VA). Student-gathered data is shown below the map.



	Abingdon (Oct. 10–20)	Danville (Oct. 15–25)	Emporia (Oct. 20–31)
Latitude (controlled)	N 36.34	N 36.35	N 36.41
Elevation (varies)	636 m	174 m	39 m



surprisingly, the results are consistent with the data in Figure 6.

While this activity certainly implies that temperature is an important variable when considering peak time, we provide a classic research paper by E.B. Matzke (1936) to discuss the fact that multiple factors (variables), outside of day length and temperature, may influence an organism. The paper describes a study that demonstrates trees close to street lights were shown to have maintained their leaves longer into the fall compared to trees farther from street lights.

Exploring other patterns

At the conclusion of the activity, we give students the opportunity to look for other variables that might explain leaf-color change. We also encourage students to examine other interesting patterns—such as the start of, peak, length of, and intensity of fall colors—to look for possible explanations. To do this, students consider what data is available from the websites and identify potential tests that would have the capability of falsifying their hypotheses. With the availability of online data, most students can design and test these hypotheses in a few days. For instance, we have had students explore factors such as average low temperature, degree growing days (accumulation of heat over a particular biologically important threshold, e.g., 25°C), and precipitation.

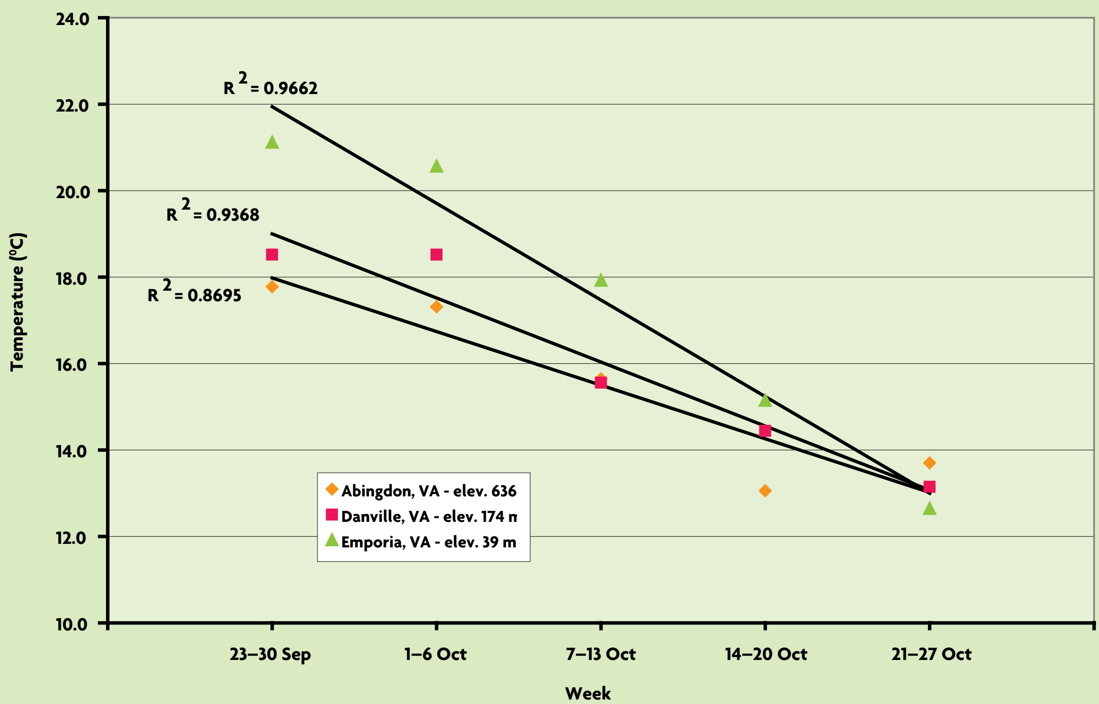
Students have found it difficult to identify any major relationships with peak time for leaf color and other weather variables. This is not surprising considering that day length (again, more correctly length of darkness) and temperature are the two driving factors influencing the start and progression of leaf-color change. Once students have completed their tests, we often emphasize that negative results showing no correlation are just as important as positive results in helping scientists gain knowledge.

Fall colors are such an attraction that tourism organizations in many states provide updates during the fall to describe how the colors are progressing (e.g., the Virginia map). This information

FIGURE 6

Average temperature versus week at different elevations.

Higher elevations appear to have a cooler temperature suggesting that temperature may be one of the factors influencing leaf color change in the fall.



may be in formats such as written descriptions or detailed maps. We prefer the Foliage Network (see “Resources”) that contains foliage reports for the past five years for a variety of states because it provides reports in map form for much of the eastern United States. Further, the resource provides frequent updates during the peak season (i.e., more data collection points than most resources). Frequent reporting times allow students the option to examine leaf-color change across broad regions as it occurs. We caution students that these foliage reports are probably not completely accurate because the website is focused on reporting for tourism not science. Therefore, when examining their hypotheses, we encourage students to account for error possibly present in the data acquired from this website.

The relevancy of leaf color change in some areas can be very beneficial in getting students engaged in inquiry and exploring relationships among organisms and abiotic environmental variables. However, this activity can also be used as a way to encourage students to think about factors that influence climate and weather in different areas around the world. An obvious extension of this lesson would be for students to look at factors that influence climate latitudinally, including the tilt of Earth and light from the Sun. Also, students can see from the map of Virginia that the east-west pattern appears to be related to elevation (Figures 5, p. 35, and 6). Therefore, students can use the data from the internet to explore the relationship between elevation and temperature and the relationship between adiabatic cooling and rainfall (which can be used to explain the rain shadow on the east side of the Rocky Mountains).

For an ecology unit, one of the more powerful next steps is the examination of biome distributions. For instance, when looking at the peak time map from The Weather Channel (Figure 1, p. xx), students often observe the lack of color in some regions of the United States. This observation lends itself to an exploration of biomes—students can look at climate in those regions by collecting the average temperature and rainfall data for several years using the internet and then creating their own climate graphs. The biome exploration provides an opportunity to discuss natural selection caused by abiotic factors such as temperature and precipitation. The study of biomes becomes more interesting to students when they design their own climate graphs to explain differences in certain regions and understand these patterns.

Using the inquiry approach to explore relevant questions provides a greater opportunity for students to become engaged and build a lasting framework of knowledge. Unfortunately, if students do not see results within a short timeframe, inquiry activities can lose appeal and impact. Inquiry activities that allow students to collect and interpret some types of data quickly may be more successful in bridging the gap. The activity described in this article allows students to see that some questions cannot be answered immediately without long-term data. At the same time, the activity allows students to ask questions and obtain long-term data quickly to assist them in developing and evaluating hypotheses. ■

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References

Matzke, E.B. 1936. The effect of street lights in delaying leaf-fall in certain trees. *American Journal of Botany.* 23(6): 446–452.

University of Virginia Climatology Office. 2006. Typical fall foliage peak color periods for Virginia. *http://climate.virginia.edu/foliage.htm*

Resources

Google Earth: *http://earth.google.com*

The Foliage Network (Foliage Reports): *www.foliagenetwork.com*

The Weather Channel (Fall Foliage Maps): *www.weather.com/maps/fallfoliage.html*

U.S. Naval Observatory (Sun Rise/Set): *http://aa.usno.navy.mil/data/docs/Dur_OneYear.html*

Weather Underground: *www.wunderground.com*