Duke Farms

Finally Fall: Why Do Leaves Change Color in Autumn?

Sugar maples in their fall splendor

From spring through summer, leaves are green. They come in every shade of this calm-inducing color, but they are green nonetheless. Then presto-change-o, once October arrives, our eastern woodlands transition into the vibrant gold and crimson hues of fall. The transformation is magical, but have you ever wondered why is this happening?

No, mother nature is not putting on this spectacular show to impress us mere mortals. It's really all about energy. Leaves are the factories where the food necessary to fuel tree growth is manufactured. This food making takes place in cells containing chlorophyll. Chlorophyll is made up of photosensitive pigments which absorb the energy from sunlight and power the transformation of carbon dioxide and water into sugars and starch. We call this process **photosynthesis**, *aka* making plant food with light!

Birch leaves turn yellow in Autumn

Chlorophyll absorbs red, orange, and blue light from the sun but reflects green wavelengths, which is why chlorophyll appears green to the human eye and make leaves look (you guessed it) green. What's not so well known is that in addition to the green from chlorophyll, leaves also contain other pigments that help the process along. These include carotenes which are orange in color and xanthophylls which are yellow. Plants use these molecules to assist chlorophyll in the absorption of light and to help protect leaves from solar radiation damage. During the active growing season, these underlying pigments are masked by the overpowering amount of chlorophyll and they are invisible to us.

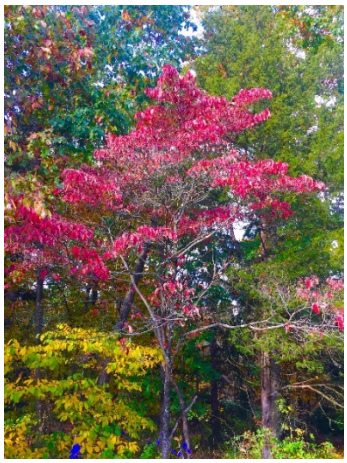
Anthocyanins and carotenes give sugar maples their vibrant color

In autumn, plants stop making chlorophyll and then start breaking down chlorophyll into smaller molecules. As chlorophyll goes away, the other underlying pigments start to show their colors. This is why leaves turn yellow and orange in autumn. The yellow, gold and orange colors created by carotenoids and xanthophylls remain fairly constant from year to year because these pigments are always present in leaves and the amount does not change much in response to weather. Unless there's severe drought, trees like birches and hickories will always turn yellow.

Red colors, come from pigments called anthocyanins, are another story. Not all trees make this pigment, but in trees like dogwoods and sugar maples, it seems to play an important role in protecting the leaves from excess sunlight and helping trees glean any last remaining nutrients from the leaves before they drop. The reason we see more vivid reds during some years is that lots of sunny days and dry weather increase the sugar concentration in tree sap, triggering the tree to produce anthocyanins to collect any remaining sugars in the leaves. This little bit of extra nutrition may be the thing that helps the trees survive a bad winter. Other conditions that may

trigger strong anthocyanin production include near-freezing temperatures, low nutrient levels and insect stressors.

Then there is anthocyanin's role in chlorophyll production. It takes a whole lot of energy to make chlorophyll. In autumn, trees can save a lot of energy if they break down chlorophyll and move the molecules out of their leaves before they fall off by reabsorbing the molecules that make up chlorophyll into the trunks for storage. Then, in the spring when it's sunny enough to start grow again, the trees can access those stored molecules to remake the chlorophyll without having to start from scratch. Anthocyanins help trees move the component molecules into the trunk in fall and back into their twigs the next spring so they can use them to reconstitute chlorophyll. The problem for the tree is that it takes energy to make the red anthocyanins, too. Not as much as making chlorophyll from scratch, but it can be an energy dilemma. The amount of red pigment really depends a lot on how much sugar a tree has stored during the growing season.



Anthocyanins turn dogwoods red

Trees get their first cues to begin decomposition of chlorophyll from changes in the length of daylight as well as the dropping temperatures of fall. The amount of rain in a year also affects autumn leaf color. Overly warm temperatures or a dry fall can delay the arrival of fall colors by a few weeks. A warm, wet period during fall will lower the intensity, or brightness, of autumn colors. A severe early frost or prolonged drought can kill the leaves, turning them brown and causing them to drop early without a lot of color happening. The most intense colors form when springs are warm and wet, summers are not too hot or dry and fall has plenty of warm sunny days with cold, but not freezing nights.

As the fall colors appear, other changes are taking place. At the point where the stem of the leaf is attached to the tree, a special layer of cells develops and gradually severs the tissues that support the leaf. This is called the **abscission layer**. It acts a lot like a storm window. When a leaf is finally blown off by the wind or falls from its own weight, it leaves behind a leaf scar which is usually unique to the species and can help with winter tree identification.

Most of the deciduous, broad-leaved trees in the Northeast lose their leaves in the fall. However, the dead brown leaves of the oaks and beeches and a few other species may stay on the tree until growth starts again in the spring. In the South, where the winters are mild, some of the broad-leaved trees are evergreen; that is, the leaves stay on the trees during winter and keep their green color.

How Will Climate Change Affect Fall Colors?

The two main environmental factors that trees cue in on when it comes to fall color are daylength and temperature. Shortening days in August and September is the main trigger to begin the process of leaf senescence. Daylength signals chlorophyll to stop being produced and to begin to degrade. Trees use daylength as their main cue because it is a reliable sign of the coming of winter as daylength lessens with regularity depending on where the earth is in its orbit around the sun. Temperatures, however, can vary greatly due to variations in the weather. Plants take temperature into account in determining how fast chlorophyll breaks down as well as how much of the color pigments are produced or expressed. If

the fall is cool or colder than average, trees hasten the breakdown of chlorophyll and leaf color changes sooner. If it is warmer than normal, the onset of fall colors will be delayed or very subdued. With climate change, all signs point to warming temperatures over the long haul.

It's not just about the world getting warmer, climate change is also wreaking havoc with predictability of seasonal cues. If the daylength and temperature relationship becomes totally out of sync, then color development will be totally unpredictable. Some trees will attain peak color much later in the season than in the past, while others may change from green to brown without the intermediate color production period.

Warming overall temperatures may also extend the growing season to late fall when light levels are reduced due to the lower sun angle. Less light combined with shorter days is not conducive to photosynthesis, but without the massive breakdown of chlorophyll, leaves will continue to try to do their job. So, respiration and burning of stored sugars would increase while photosynthesis and sugar production decreases. This results in a carbohydrate deficit. Since excess sugars are necessary to stimulate the production of anthocyanins, which give leaves their red fall color, warmer global temps could result is a lot less red.

Subdued leaf color could result from our warming climate

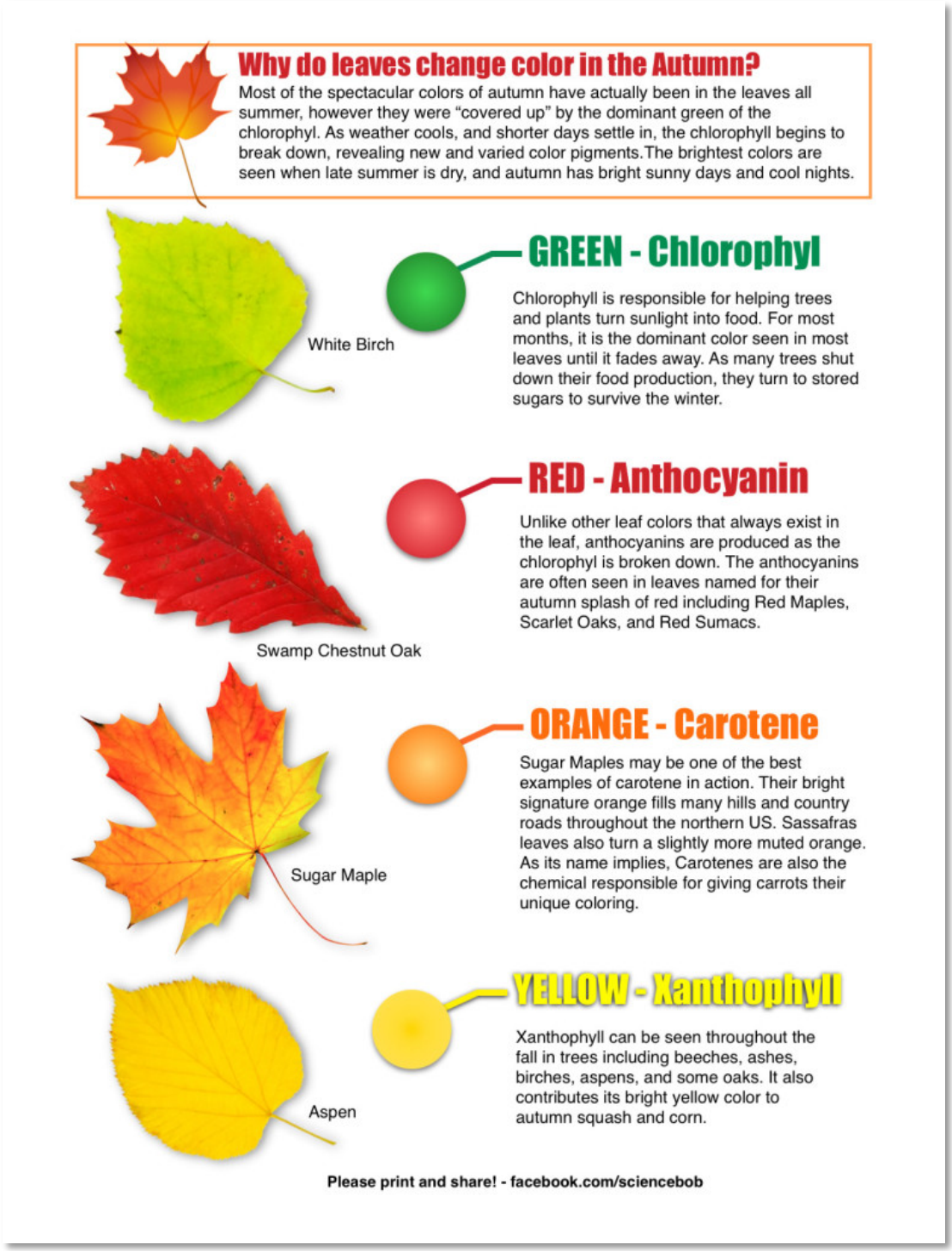
Climate change is also causing extremes in precipitation events and soil moisture. Higher precipitation in fall lowers the intensity of leaf color, not because it washes out the pigments but rather, because the increased cloud cover and low light levels reduce photosynthesis, again lowering sugar production. Storms also rip leaves off trees and cause stress or increase soil moisture and extend the growing season. Perhaps the biggest impact from the warming climate are longer and more severe periods of drought. Drought causes the leaves to turn brown, dry up, and drop before their time.

An even bigger unknown is how climate change will affect tree distributions. One glaring example is the sugar maple. This tree is adapted to colder temperatures and is the dominant tree in the forests of New England, but as temperatures warm, it may die out in the United States. The tree is predicted to migrate north into Canada, leaving few trees in the U.S., which will decimate maple syrup production in New England and wreak economic havoc in Vermont, New Hampshire, New York, and Maine. The loss of the flame colored trees in fall will do the same to the leaf-peeping tourist industry, but perhaps the saddest thing of all is that it will rob us and our children, and our children's children the unbridled joy that comes with seeing the brilliant colors of the forest in fall, and that would be a tragedy.

Activity 1: Look for Trees and Leaves with the 4 Kinds of Pigments

Go on a nature walk in a woodland sometime in mid to late October or the beginning of November. It would be wonderful if you could come to Duke Farms for this activity as we have diverse woodlands with many species of trees. Use the following key to recognize the pigments in leaves and trees.

**See more info about this chart.*

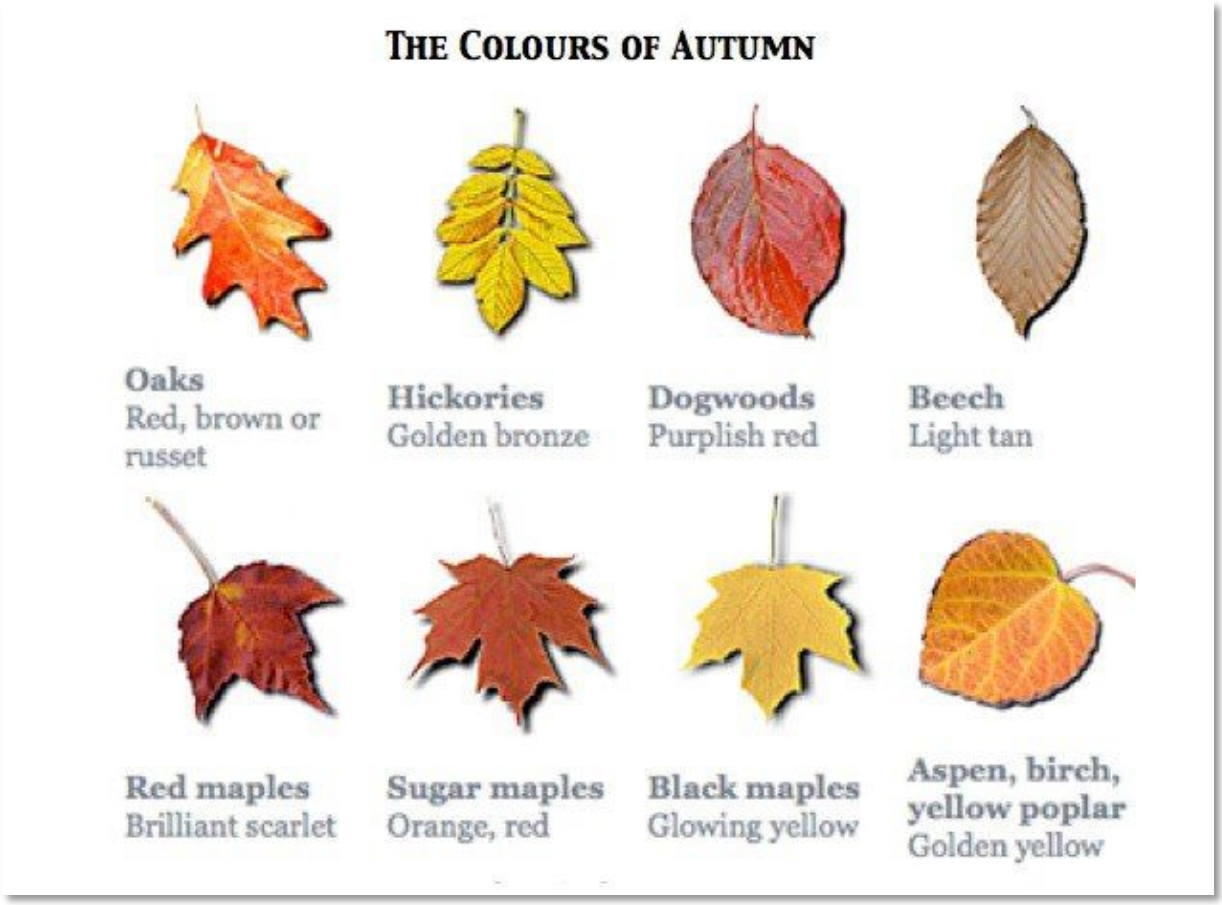


Activity 2: Try to Identify Leaves by their Shape and Color

Download a free leaf or tree identification app for your mobile device, we recommend iNaturalist. This National Geographic sponsored app helps you identify plants and animals by snapping a photo. You just take a photo and submit it to the app, then then provides you a list and images of possibilities. It's very cool!

As you take the woodland walk in Activity 1, snap photos of the trees and leaves as you go. Observe and identify what leaves you find and their associated colors and pigments. Record your observations in INaturalist.

Another option is to use a key like the one below to identify leaves by shape and color. Record your observations in a notebook or journal. Repeat this activity multiple years in a row and record your observations over time! See how woodlands near you are changing as the years pass!



Find details about this leaf guide here

Additional Resources:

- Why Leaves Change Color in Fall
- Why Leaves Change Color
- Learning Trees by Fall Color
- Climate Forest Atlas
- Climate change and fall colors from Harvard
- Will Climate Change Affect Leaf Color?

For more information about using this lesson in a multidisciplinary manner, including alignment to climate change curriculum, contact Kate Reilly, Manager of Education at kreilly@dukefarms.org