The Department of
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FORESTRY AND NATURAL RESOURCES
Frequently Asked Question Series

Why Leaves Change Color - The Physiological Basis

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Myths about Jack Frost are so ingrained in our folklore it is difficult to separate fact from fantasy when explaining the spectacle of autumn color. These legends compensated for the lack of knowledge concerning the natural phenomenon. Today, however, the display of color we enjoy each fall is explained by understanding plant pigments, the physiology and anatomy of leaves, and the influence of climate and seasonal weather conditions.

Both Hardwoods and Conifers Develop Autumn Color

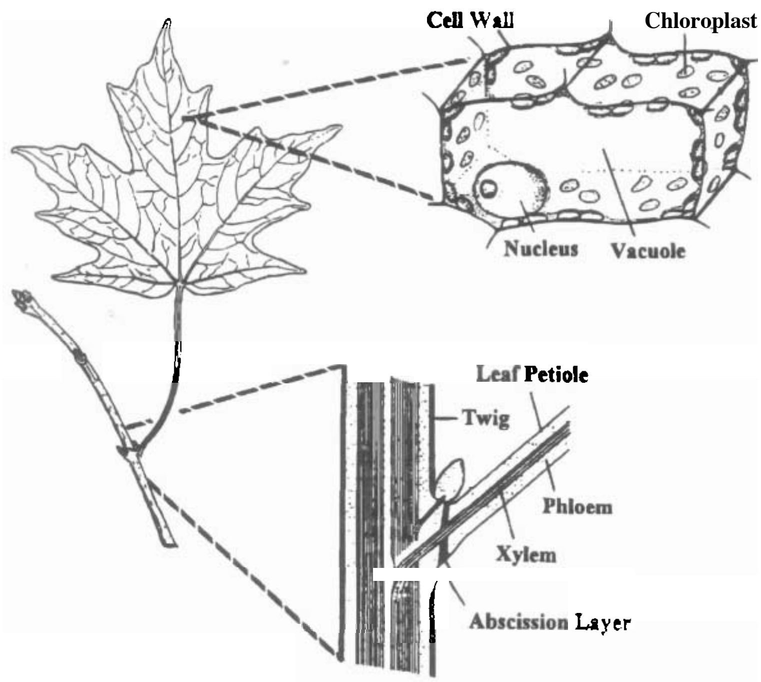
Hardwood trees, with their broad leaves that change color almost in unison, generally display the most spectacular autumn color. However, a few conifer species, such as larches and baldcypress, which drop all their needles each fall, develop striking color too. Even the evergreen conifers develop autumn color, but the color changes are restricted to the older needles. Two-year-old or older needles are shed from conifer trees each year after they turn yellow, brown, or rarely reddish. These interior needles appear in sharp contrast to the green needles on the ends of the shoots. Yet even in the most conspicuous cases, as in pines and spruces, autumn color is muted by the green of the remaining current year needles. Residents often become unnecessarily alarmed in the autumn when the interior needles of their conifers turn color, mistakenly interpreting this natural condition as sign of a disease or insect problem. Regardless of the kind of tree, the reasons for fall color are the same.

Leaf Pigments and Seasonal Changes

Four leaf pigments account for leaf color and its changes in the autumn; chlorophylls, carotenoids, tannins, and anthocyanins.

Chlorophyll located in tiny organelles called chloroplasts in the cytoplasm of cells gives leaves and other plant parts their green color. This pigment absorbs the radiant energy of the sun and is essential for the process of photosynthesis in which carbon dioxide and water are transformed to the sugars necessary for tree growth. Throughout the growing season in a healthy tree, chlorophyll is continuously being produced and destroyed. Even though light is necessary for the formation of chlorophyll, continued exposure of new chlorophyll to sunlight with its damaging high-energy ultraviolet wavelengths will destroy the pigment. Hence, if a leaf is to remain green, new chlorophyll must be made constantly.

As days get shorter and temperatures cooler in the autumn, important physiological processes are triggered that make conditions for chlorophyll production less favorable. Nitrogen and phosphorus are slowly withdrawn from the leaves for storage in twigs and branches during the dormant winter period. The loss of these nutrients, essential for chlorophyll production, coupled with the reduced exposure of leaves to light as days get shorter, gradually stops the production of chlorophyll. The green color of leaves fades as the production of new chlorophyll diminishes and the existing chlorophyll is degraded. The timing of chlorophyll loss varies among different kinds of trees, accounting for some leaves that remain green longer than others.



Carotenoid pigments, responsible for the yellow and orange colors, also are located in the chloroplasts and assist chlorophyll in the capture of sunlight for photosynthesis. These yellowish pigments are always present in leaves, but are not visible for most of the year because there are larger amounts of green chlorophyll. As chlorophyll degrades, the yellowish colors become apparent and give leaves part of their autumn splendor. It is the unmasking of the carotenoids that account for the yellow color of Norway maple, Ohio buckeye, yellow poplar, sycamore, birches, hickories, ashes, and many other trees. The same process also accounts for the yellowing of leaves at any time during the year due to nutrient deficiency or disease that reduces the normal production of chlorophyll.

Tannins cause the brown hues in leaves of some oaks and other trees in the autumn. Like the carotenoids. these compounds are always present, but only become visible as chlorophyll and carotenoids disappear from leaves. Tannins are bitter substances that color and flavor tea and cause unripe persimmons to pucker your mouth. They are common waste products of metabolism in trees, deposited in the cell sap inside the vacuole as well as in cell walls, and often accumulating to considerable amounts in dead tissue. The golden yellow produced in some leaves such as those of beech, result from the presence of tannins along with the yellow carotenoid pigments.

Anthocyanin pigments are responsible for the pink, red, and purple leaves of sugar and red maple, sassafras, sumac, white and scarlet oak, winged euonymus, and many other woody plants. They are formed in the cell sap inside the vacuole when sugars combine with complex compounds called anthocyanidins. The variety of pink to purple colors is due to many, slightly different compounds that can be formed. Their color is influenced by cell pH. These pigments usually are red in acid solution and may become purplish to blue if the pH of the cell sap is increased.

Anthocyanins are usually not present in leaves until they are produced during autumn coloration. A few trees, however, such as 'Crimson King' Norway maple and purple European beech have reddish leaves throughout the growing season due to anthocyanins in them. Not all trees have the genes required for production of anthocyanin pigments, and hence those trees only develop yellow and brown shades of autumn color.

Formation of Abscission Layer

Shorter days and cooler temperatures in fall initiate leaf senescence involving complex biochemical processes, which increase the enzymes in leaves that promote the breakdown of cells. One of the results is the collapse of cells in the living phloem to form an abscission layer at the base of leaf petioles where they attach to twigs. This is the point at which a leaf is eventually shed. The nonliving xylem tissues remain intact for awhile and still carry water to the leaves, but the phloem pathway for conduction of sugars out of leaves is severed. Sugars, derived from continued photosynthesis as well as from the conversion of stored starch to soluble sugars in the leaves, are trapped and are available for anthocyanin production. Trees of the same species growing together often differ in color. The colors vary because of differences in amounts of soluble sugars in the leaves for anthocyanin production. Trees exposed to the sun may continue photosynthesis and turn red while others in the shade may be yellow. A single tree may even have branches with different colored leaves due to one leaf shading another.

Best Weather for Autumn Color

Fall weather conditions affect anthocyanins more than the other pigments involved in autumn color. The shades of yellow and brown always appear, but it is the brilliant reds and purples mixed with them that impart the awesome beauty to fall landscapes. Fall weather conditions favoring formation of bright red autumn color are warm sunny days followed by cool, but not freezing, nights. Photosynthesis still occurs in leaves even while chlorophyll is declining. Rainy or cloudy days with their reduced sunlight near the time of peak coloration decrease the intensity of autumn colors by limiting photosynthesis and the sugars available for anthocyanin production.

There is an old wives' tale that claims rain washes the color out of leaves. It is not true, but the overcast conditions do reduce light intensity, and heavy rains and high winds can sweep the leaves off trees early. The common belief fostered by legends that a hard frost is necessary for good autumn color isn't true either. Freezing temperatures greatly reduce the brilliance of autumn color by killing or severely injuring the leaves, preventing physiological processes before the pigments reach their maximum development. The mythical Jack Frost who supposedly brings reds and purples to autumn trees by pinching the leaves with his icy fingers actually does more harm than good.

In Review

Both hardwood and conifer trees develop fall color.
Chlorophyll is a green pigment in chloroplast necessary for photosynthesis.
Carotenoids are assessory pigments for photosynthesis, located in chloroplast and give yellow and orange colors.
Tannins are waste products of cell processes found in vacuoles and cell walls, giving brown colors.
Anthocyanins are complex and numerous pigments generally produced in the fall from sugars and respon sible for pink to purple colors.
Abscission layer is a zone formed by collapse of phloem cells, trapping sugars in leaves and the point where a leaf is shed from a twig.
Best weather condition for autumn color are bright sunny days and cool nights.

More information can be obtained from the Purdue University, Department of Forestry and Natural Resources website www.fnr.purdue.edu

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