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# Fall Colors

Vivid fall colors in Big Bend National Park, Texas.

Credit: Juli Hennings, University of Texas Bureau of Economic Geology

What makes leaves change colors so dramatically in the fall?

Three things: leaf pigments, the weather, and the length of the days, called the *photoperiod.*

To protect themselves from freezing, broad-leafed trees in temperate areas must harvest the sugar from their leaves for the winter.

This starts when shorter days signal trees to slow the production of chlorophyll.

As photosynthesis uses up the remaining green chlorophyll, yellow pigments that are always present in the leaves show through.

Mild sunny fall days will rapidly process the chlorophyll and leave bright golds, while rainy or hot days will make for more muted colors.

Cooler nights soon trigger the production of red and purple pigments, which are thought to act as a sunscreen, further slowing photosynthesis.

These red colors are more abundant in healthier plants and may serve to warn insects away, toward weaker plants.

Eventually, the last sugars are drawn from the leaves and into the branches, trunk, and roots of the tree for storage during the winter.

Cells form at the base of the leaf, making it more likely to fall off, and at the twig end, like a scab, sealing the twig off from outside elements.

Only the vascular bundles connected to the veins of the leaf hold it to the tree.

When the leaf finally falls, its remaining nutrients are recycled into the soil to be used by the tree for future growth.

Meanwhile the bundle scar left on each twig becomes a bud for a new leaf in the spring—when the tree will use its stored energy to grow a new crown.

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# Background: Fall Colors

**Synopsis:** Nothing signals the end of summer like the colorful autumn-forest extravaganza that occurs before trees drop their leaves for winter. Three things dictate the timing and intensity of fall leaf colors: leaf pigments, the length of day, and the weather.

- The type of tree—evergreen or deciduous—determines why some trees lose their leaves for the winter while others keep them.
  - Evergreens, or conifers, are green year-round. Pine, fir, spruce, juniper, and cedar are types of evergreen trees.
    - Their needle-shaped leaves have tough wax coatings.
    - The fluids in their needles resist freezing, like antifreeze.
    - Their needles may stay on the tree for several years, only falling off because of old age.
  - Deciduous, or hardwood, trees have tender, broad leaves filled with water-soluble sugary sap. In temperate regions, these trees must protect themselves from freezing.
    - Twigs, stems, and buds can survive winter, but leaves are too tender to survive freezing. To protect them, trees slow photosynthesis and harvest their sugars, causing them to change colors.
    - Trees then drop the spent leaves to the ground, where their remaining nutrients are recycled into the soil.
    - Oaks tend to turn red, brown, or russet; maples range from bright scarlet to yellow; hickories turn golden bronze; and aspen glow in shades of gold and yellow.
- The colors we see on the outside of the leaf are controlled by the complex chemistry that goes on inside the leaf as it grows, ages, and dies.
  - Green chlorophyll, which is continually produced and consumed during the growing season, is stored in the plastids of leaves.
    - Chlorophyll is necessary for photosynthesis, enabling plants to use sunlight to manufacture sugars.
    - Chlorophyll production is so strong in the growing season that its green color dominates other pigments always present in leaves.
  - Carotenoids are also present in the plastids of deciduous tree leaves.
    - Carotenoids are yellow, gold, and orange in color, but their color is overwhelmed by the green of chlorophyll for most of the year.
  - Red and purple anthocyanins do not occur in leaves in the spring and summer.
    - Some trees produce these water-soluble pigments in response to cooler nights in the autumn and store them in the sap of their leaf cells.
    - These pigments are thought to serve as a sort of sunscreen that protects leaves from bright sunlight, slowing photosynthesis so the leaves can transport their sugars and nutrients into the twigs, branches, and roots of the tree for the winter.
    - These red colors are more abundant in healthier plants and may serve to warn egg-laying insects away, toward weaker host plants.
- The trigger that causes leaves to change color is the photoperiod—the length of the day and night.
  - From the summer solstice to the winter solstice, the length of the day progressively decreases. Trees use this as a cue to begin preparing for winter, slowing and ultimately stopping chlorophyll production.
  - In preparation for dormancy, plant cells shift to production of sugars and amino acids that serve as antifreeze for the plant, and their metabolic rate slows.
    - The remaining green chlorophyll is then consumed, unmasking the other colors of the leaves.
  - Compounds in the leaves are drawn first into stems and twigs, and then into the root system, for storage during the winter.
    - This stored energy is what the tree will use to bud out and grow an entire crown of leaves in the spring.
  - Eventually, leaves are depleted to the point that only cell walls and depleted protoplasm are left.
    - At this point, two types of cells form at the base of the leaf stem. Soft cells called *parenchyma* cells form on the leaf side, while waxy, impermeable *suberized* cells form on the tree side as a protective seal, similar to a scab.
    - Only the vascular bundles that used to be the veins of the leaf hold the leaf to the tree. When the leaf falls, it leaves a bundle scar and a bud for new growth in the spring.


**References: Fall Colors**

Science of Fall Colors | U.S. Forest Service
Autumn Leaf Color | Wikipedia
What Causes Leaves to Change Color? | FarmersAlmanac.com
Autumn Leaf Color: What's Elevation Got to Do with It? | ThoughtCo.com



Contributors: Juli Hennings, Harry Lynch



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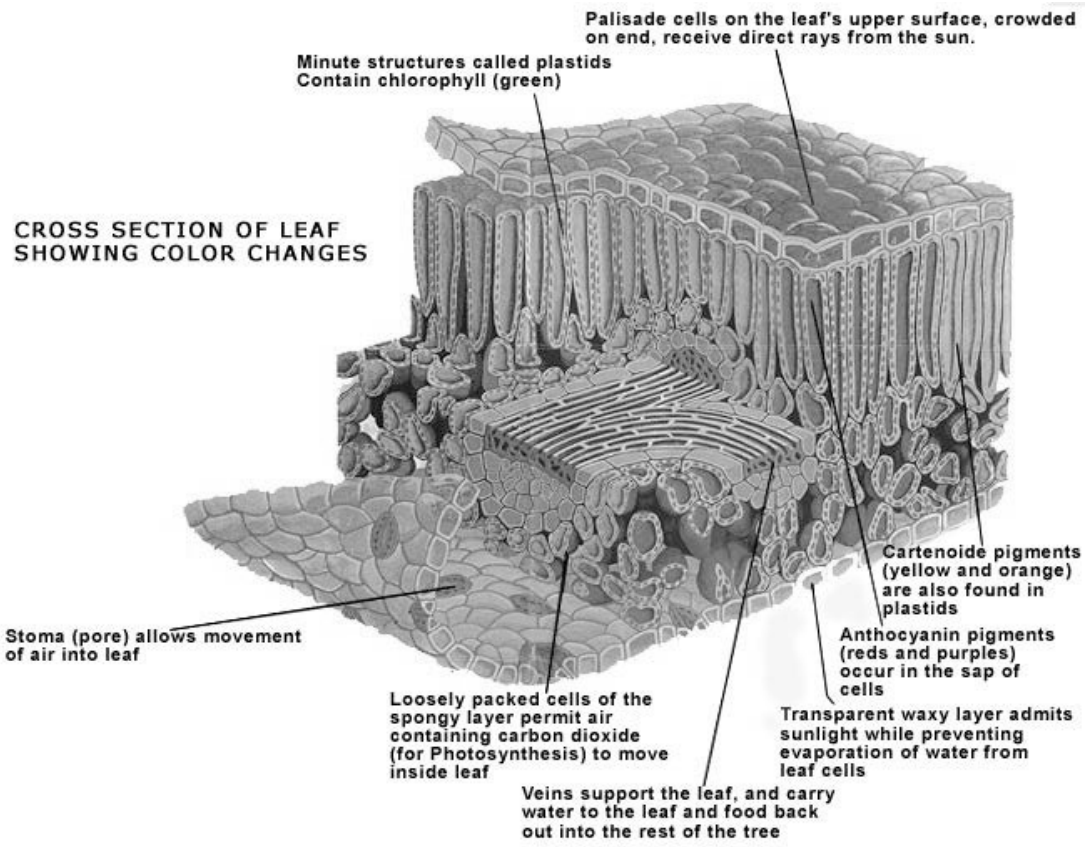
- Good fall color needs late-summer weather conditions that are "just right" during the time that chlorophyll in the leaves is dwindling. In the Northern Hemisphere, this critical time frame generally occurs from August farther north to September farther south.
  - Trees change color from the crown down as nutrient transportation to the top slows in preparation for dormancy. The topmost leaves that typically see the most sun respond more dramatically to the decrease in daylight hours.
  - Warm, sunny days encourage the leaves to make sugars. The most spectacular displays occur after ideal conditions of sunny late summer days and cooling nighttime temperatures in early fall.
    - If it is especially cloudy, rainy, dry, or hot during this critical period, fall colors will be more muted.
  - Lower temperatures may encourage leaves on trees at higher elevation to slow chlorophyll production earlier.
    - Generally, temperature decreases 3–5 degrees per 100 ft of elevation, depending on weather conditions.
  - Since yellows and golds come from carotenoids that are always present in leaves, these colors are fairly consistent year to year.
  - Cooling (but not freezing) autumn nights signal the leaves to produce red, crimson, and purple anthocyanins.
    - Variation in early fall nighttime temperatures determines the level of red in the landscape.
  - Soil moisture also impacts fall colors. Summer droughts can delay the onset of fall by a couple of weeks, while excess summer rainfall can cause fungal outbreaks that cause leaves to wither and drop off before changing color.




Cross section of a leaf, showing color changes.

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