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Fall Colors: The Science of Autumn Leaves

The Las Vegas Valley is not known for its vivid autumn colors compared to other areas of the country where deciduous trees dominate. However, subtle changes in the leaves are occurring as the plants prepare for winter. The explanation for the changing color of leaves involves factors from various science disciplines and provides teachers with the opportunity to review many science-related concepts.

As the seasons change from summer to autumn, the Northern Hemisphere receives less direct sunlight due to the average 23.5° tilt of the Earth's axis. The daylight hours decrease and the temperatures cool. The trees prepare for the upcoming winter season as the green colors change to shades of red, yellow, or brown. Some of the pigments responsible for the spectrum of fall colors are present during the spring and summer, but are masked by the abundance of chlorophyll ($C_{55}H_{70}MgN_4O_6$). Chlorophyll (most plants contain types a and b) absorbs mainly red and blue wavelengths and the light reflected appears green. The absorption spectrum for chlorophyll a is shown in Figure 1. Chlorophyll is found in the disc-shaped chloroplasts, which are the site of photosynthesis. During the complex endothermic reaction of photosynthesis, light energy absorbed by the chlorophyll is used by plants to convert carbon dioxide and water into oxygen and sugar (stored chemical energy). The carbohydrates (sugars) are stored or used by the plant to carry out life functions such as to grow, heal, and reproduce. Although chlorophyll is the most abundant pigment during photosynthesis, it is not a stable compound.

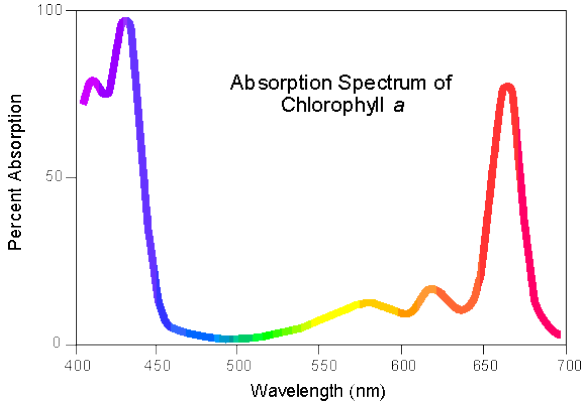

Figure 1: Absorption Spectrum of Chlorophyll a
From: SciFun.org: Chemical of the Week– Chlorophyll

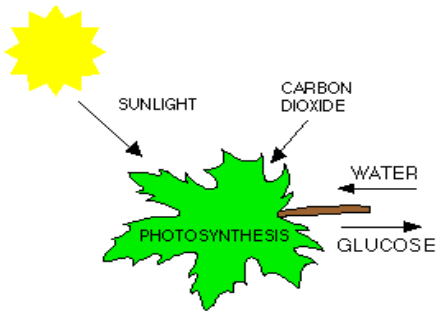

Figure 2: Overview of Photosynthesis
From: Science Made Simple- Autumn Leaf Colors

The color change in the leaves occurs as the chlorophyll breaks down because the trees are preparing to shed their leaves. In the temperate zones, the watery tissue of the leaves would be destroyed in freezing temperatures. In addition, the broad surface of the leaves provide the opportunity for the accumulation of snow and ice, which can break the tree's branches. As a self-preservation mechanism, the cool nights of the autumn trigger an adaptation in plants. The trees stop producing the chemical, auxin, and this enables the formation of a corky membrane to grow between the branch and the leaves. The membrane, known as the abscission (separation) layer, essentially cuts off the circulation of water and nutrients to the leaf. As a result, the chlorophyll quickly decomposes allowing the other pigments to be seen.

Written by: Elizabeth Marconi

Nature's palette also includes the yellowish-orange carotenoid pigments (found in corn, bananas, buttercups, and carrots), the reddish-purple pigment anthocyanin (found in cranberries, cherries, plums, and eggplant), and the brown tannins (provide the color and flavor of tea). Carotenoids are accessory pigments that absorb mostly blue-green and blue light and transfer the light energy to chlorophyll, which uses the energy during photosynthesis. Once the chlorophyll breaks down in the autumn, the carotenoids are left and the leaves appear a hue of yellow or orange. The anthocyanin is produced when high concentrations of sugar react with the protein in the leaves. In the presence of bright sunlight, the anthocyanin production is enhanced. Anthocyanin is also water soluble and its color is determined by the pH of the sap within the vacuole of the plant cell. In an acidic environment, the pigment appears more red. If the sap is less acidic, then the color will appear more purple. The tannis are a common waste product of tree metabolism. They are present throughout the year, but only appear as the carotenoids and chlorophyll break down.

What do autumn leaves and bananas have in common?

Chlorophyll is the pigment responsible for the green color of unripe bananas. As the chlorophyll breaks down, the yellow color of the banana that was there all along becomes visible. The yellow and orange pigments of autumn leaves were also in the leaf all year, but were not visible until the chlorophyll broke down.

The weather impacts the intensity of the color of the autumn leaves. In fact, the most vivid autumn colors are produced when dry, sunny days are followed by cool, dry nights. These conditions promote the production of anthocyanin because the sugar-rich leaves are exposed to the sunlight and the cool nights promote the sealing off of the vein to the leaf. A decrease in the amount of rainfall throughout the spring and summer months can decrease the colors of autumn. Since carotene is always present in the leaves, the shades of yellow in the fall remain consistent from year to year. The impact of rainfall on leaf color explains why the trees planted in Southern Nevada do not display intense autumnal colors.

The interaction of the biochemical processes of plants with the environment provide a colorful display that varies from year to year. The discussion of why the leaves change color provides teachers with the opportunity to review absorption spectrums, the formula and process of photosynthesis, cell structure and function, the reason for the seasons, environmental adaptations, solubility and pH levels. Teachers could perform a paper chromatography lab with their students to illustrate the presence of various pigments within the leaves of different plants. Teachers can also use the chromatography of a dry erase marker as an analogy to show how various pigments may be present, but not apparent. Links to sample paper chromatography labs are listed in the related websites section below.

Related Websites:

US Department of Agriculture: Why Leaves Change Color- www.na.fs.fed.us/spfo/pubs/misc/leaves/leaves.htm

Science Made Simple: Autumn Leaf Colors- www.sciencemadesimple.com/leaves.html

Science is Fun: The Chemistry of Autumn Colors– scifun.chem.wisc.edu/CHEMWEEK/fallcolr/fallcolr.html

Chemical of the Week: Chlorophyll- scifun.chem.wisc.edu/chemweek/CHLRPHYL/Chlrphyl.html

Chromatography Basics- sciencespot.net/Media/FrnsScience/chromacard.pdf

Purdue University: Analysis of Plant Pigments- www.chem.purdue.edu/teacher/table_of_contents/UVVUS/UVVIS.Plant%20Pigments_CH.pdf