

The Reds of Autumn

By PRU FOSTER

Red! It stands out. We use red to get attention or to warn of danger. Part of the reason red grabs our attention is because it scatters relatively little in the Earth's atmosphere. The sky is blue, at the opposite end of the visible spectrum, because blue light from the sun scatters the most in our atmosphere and thus more of it reaches our eye. Because red light scatters so little, we can see it from long distances and under less-than-ideal conditions—such as through fog or a lot of atmosphere at sunset. The visibility of red makes it a useful warning color.

Warning Coloration in Butterflies. From frogs to snakes to ladybugs, animals use red coloring as a warning that they are poisonous or taste bad. This is called aposematism (advertising a warning) and is so effective that other animals hitchhike on this signaling system, copying poisonous animals' color patterns. An example of this mimicry is the non-poisonous Red-spotted Purple butterfly (*Limenitis arthemis astyanax*) which lives in Maryland. It has conspicuous red-orange spots on its wings, similar to those of the co-occurring and poisonous Pipevine Swallowtail (*Battus philenor*).

However, north of here—where the Pipevine Swallowtail doesn't occur—*Limenitis arthemis astyanax* has a different form called the White Admiral*. The White Admiral is distinguished by a wide white band on black wings and lacks the bright warning spots on the wings found in the southern Red-spotted Purple's population. One might think these are separate species, but they are the *same species with local adaptations*. Where White Admirals occur, there are no Pipevine Swallowtails to teach the local predators to avoid its toxic warning colors and thus no benefit to mimicking them.



Scarlet Oak (*Quercus coccinea*) is an excellent tree for the home garden that grows fast and matures relatively early while supporting moths, squirrels, birds, and even black bears. Photo by Faith Campbell.

Coevolution Theory of Red Autumnal Leaves. The flashy autumnal reds in leaves may have evolved to serve a similar purpose to aposematism in the animal kingdom. The coevolution theory of autumnal red leaves holds that the red coloration evolved to combat aphid damage. In autumn, aphids seek out a place to lay their eggs where, the following spring, their newly hatched young can readily find yummy leaves to munch on. Aphids tend to choose greener-leaved trees to lay their eggs on and red-leaved trees tend to have less aphid damage. Even within the same species—the aphids prefer the green-leaved individuals over the red-leaved ones. In areas with larger aphid populations, the number of tree species that have red fall foliage increases.

Finally, the amount of phenolics in a leaf—which serves as a chemical defense against insect feeding—correlates with red autumnal color. The coevolutionary theory hypothesizes that it was advantageous for trees to produce red leaves at the time of year that effectively deters

aphids and simultaneously advantageous for the aphids to avoid poisonous red leaves.

If autumnal red leaves reduce aphid damage so effectively, you may wonder why all trees don't produce red leaves in the autumn. It's because there is a cost to producing the red pigment—anthocyanin. Unlike the other main pigments in leaves, anthocyanins are generally not present in leaves during the growing season. Instead, it is produced through the breakdown of sugars in the leaf in the presence of bright sunlight as the leaves are dying. The disadvantage of this pigment production is that sugars used to make the anthocyanin have been allocated away from growth, regulation, or stress mitigation. We can see this in apple lineages. Wild apples tend to have more red autumnal leaves than domesticated apples, but they also have smaller fruits. This is because they've used sugars to protect the tree from aphid attack rather than allocating them to plump up the fruits.

*If you aren't confused yet, we'll try harder. There is a separate species of butterfly—called White Admiral (*Limenitis camilla*)—native to Europe, that is unrelated to the white form of the Red-spotted Purple. We're definitely going to be quizzing you on this!

Green and yellow pigments. Unlike the red pigment, green (chlorophyll) and orange-yellow (carotenoid) pigments are present in leaves throughout the growing season. We usually only see the green of the chlorophyll before autumn, because at that time the chlorophyll is far more abundant than the other pigments. During the growing season, chlorophyll is continually destroyed (via photosynthesis) and continually produced (via biosynthesis)—maintaining levels high enough to make most leaves appear green.

But in late summer, as deciduous trees prepare to drop their leaves, they grow a layer of cork-like cells at the base of their leaf stems. This cuts off the flow of water and minerals into the leaf stopping biosynthesis but not photosynthesis. As a result, the abundance of chlorophyll in the leaf drops. As it does so, carotenoids, which are more stable than chlorophyll, begin to shine through creating the glorious yellows and oranges of autumn leaves. In some species, anthocyanin is produced at this time—providing the spectacular reds. Sometimes we can see the stages of chlorophyll decay in one leaf as the veins will have more rich fluids in them than the space between the veins will have—creating those stunning leaves with green veins and yellow, orange, or red intervein areas. Prized leaf finds.

Europe has far fewer autumnal reds.

Further evidence that autumnal red colors evolved as a way to reduce insect damage, comes from the observation that there are far fewer autumnal reds native to Europe. In northern Europe, there are only four woody species with red autumn leaves; all of Europe hosts just 24. In contrast, North America is home to 89 species with red autumn leaves and East Asia has a whooping 152 species. Why the difference? One theory is that the insect



The luscious autumn colors of staghorn sumac (*Rhus typhina*) are difficult to surpass. Photo by Lauren Hubbard.

pressure underlying the benefit of red autumn leaves may not be as strong in Europe.

During the Tertiary Period, 65 million years ago, there were repeated cooling and warming cycles on Earth. Glaciers extended southward in the northern hemisphere during the ice ages and retreated towards the poles during the interglacial periods. As the ice expanded and retreated, trees and insects in North America and Eastern Asia could easily migrate north and south since the mountain ranges in these regions run primarily north to south. But in Europe, the Alps run roughly east-west, and as ice sheets moved southward, tree-munching insects may have been driven extinct if they could not cross the mountains. Without the insect repelling advantages, the energy costs of making red pigments would make red-leaved autumnal species less competitive.

Red leaves as sunscreen. There are a few competing theories as to why leaves turn red in autumn. The most prominent of these is that anthocyanin facilitates an increase in the rate at which the host plant reabsorbs nutrients from the dying leaves. Anthocyanins can give this resource boost to plants because they are akin to sunscreen. The red pigment acts to prevent photoinhibition which is a reduction in the rate of photosynthesis caused by too much light. Anthocyanin thus helps to keep the leaf photosynthesizing longer into the autumn thereby increasing nutrient flow from the dying leaf back to the main body of the tree. Anthocyanins are so effective at photo-protection that there is active research into using them medicinally for skin aging and eye health. Amazingly, anthocyanin is also known to have anti-inflammatory, antioxidant, anti-diabetic, and anti-bacterial capacities.

Here in Maryland, we are lucky that many native species produce natural anthocyanins in the autumn. If you want to see red, here are some great plants to include in your landscape: Red Maple (*Acer rubrum*), Black Gum (*Nyssa sylvatica*), Serviceberry (*Amelanchier spp.*), Red Chokeberry (*Aronia arbutifolia*), Black chokeberry (*Aronia melanocarpa*), Green hawthorne (*Crataegus viridis*), Maple-leaf viburnum (*Viburnum acerifolium*), Virginia sweetspire (*Itea virginica*), blueberry (*Vaccinium spp.*) and the vine, Virginia creeper (*Parthenocissus quinquefolius*). It's best for biodiversity to use straight species, rather than cultivars, so animals, fungi, and others can support and be supported by our plantings. Here's hoping you witness some anthocyanin spectacles this fall!

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