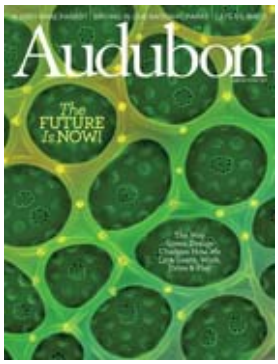

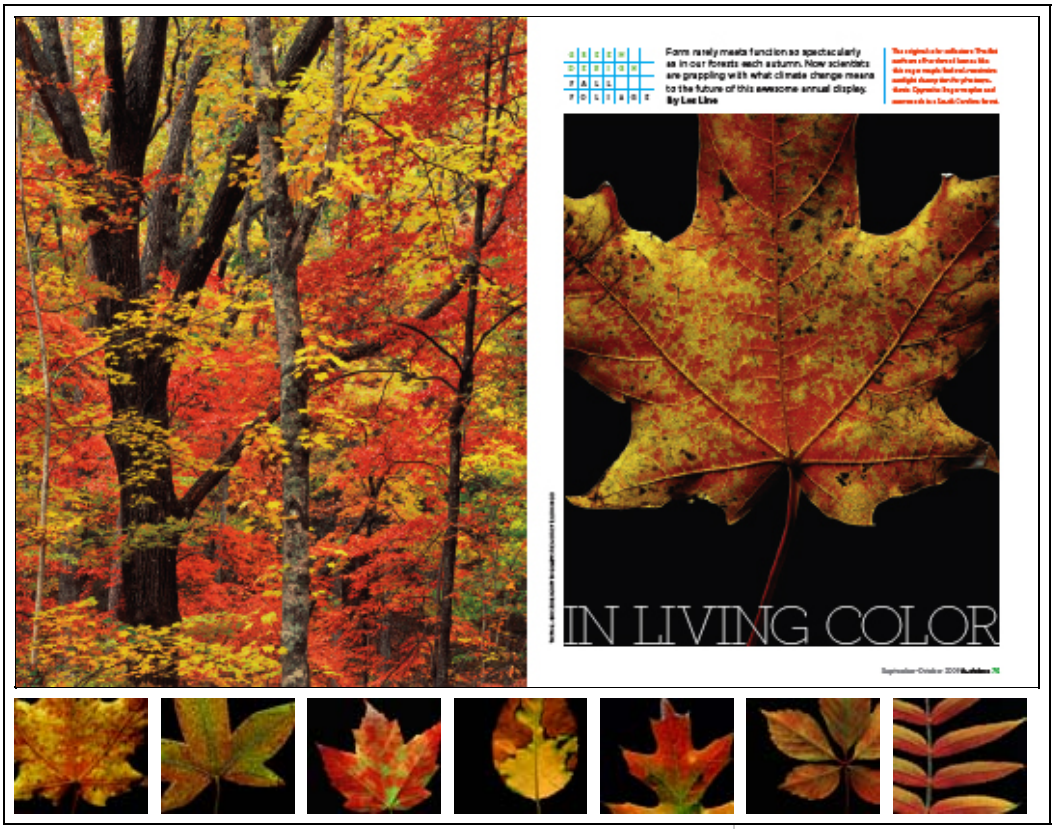

Green Design: Fall Foliage
In Living Color
Form rarely meets function so spectacularly as in our forests each autumn. Now scientists are grappling with what climate change means to the future of this awesome annual display.
By Les Line

Lamenting that "the autumnal change of our woods has not made a deep impression" on American literature, Henry David Thoreau left his Concord, Massachusetts, home in April 1859 to deliver an 11,700-word, tree-by-tree lecture on the subject that must have kept his audience over in

Lynn fidgeting in their seats for at least two hours. Rich prose to be sure, and full of quotable lines. But my friend Hal Borland, an eloquent countryman of the next century who lived in a Connecticut farmhouse beside the Housatonic River, needed only a single paragraph to sum up nature's most widely anticipated spectacle: that all-too-brief time in fall when leaves in our eastern hardwood forests flaunt their best hues.

"There is so much color, and such vivid color, that it overwhelms the adjectives," Hal wrote. "New Englanders simply refer to it as 'the color.' The sugar maples turn yellow, sunshine yellow, with now and then a tinge of pink. The swamp maples turn red, almost all the shades of red, so that the valleys are like carmine rivers. The birches and aspens turn golden and coppery. [And] the white ashes go through that incredible series of colors that range from yellowish-green to blue-tan to greenish-blue to purple, honest-to-God purple, and then bronze, to tan, and to rust."

Ah, leaf-peeping season. From the Blue Ridge Mountains of Georgia to the White Mountains of New Hampshire, from the Ozark Mountains of Arkansas to the Lake Superior country of Wisconsin, millions of Americans will drive to the woods, filling megapixels with snapshots of rolling hills and village greens in full autumn splendor while pumping millions of dollars into local economies. They will endure traffic jams on narrow, curvy roads and long waits for food at bucolic inns in order to be amazed by a phenomenon that science cannot fully explain. Indeed, it seems like researchers announce new theories about "autumnal senescence"—the changing of colors and the falling of leaves—every year at the first hint of yellow and red in the green leaves of summer.

Of course, serious fall color displays aren't limited to forests east of the prairies and plains. Views of golden ranks of quaking aspens on Rocky Mountain slopes can be breathtaking, luring thousands of peepers to high-elevation towns like, well, Aspen. But even Coloradoans yearn to see Vermont in October. And now we're being told that rising levels of carbon dioxide in the atmosphere are affecting the big show. That leaves are turning later and later. And that by 2050 it might be well into November before peak color is reached in New England. The bright side, some scientists say, is that fall colors will become more intense because of elevated CO_2 levels.

I believe them. I haven't kept notes, but certainly the great sugar maple down by our fence shows its gold much later

than it did 30 years ago, when we moved into our country home on the eastern rim of New York's mid-Hudson Valley. *Acer saccharum,* the one tree that most leaf-peepers are able to recognize even if they couldn't tell a tulip poplar from a tupelo. Botanists tell us that the round-topped sugar maple may live for 250 years, attaining a height of 100 feet where a special specimen stands by itself. Our tree is massive, with a girth of nearly 11 feet, and I can imagine it as a stout sapling during Revolutionary times when our road was a rutted wagon track over the mountain and settlers told their children that Jack Frost, an elfish character from English folklore, painted the forests. The belief that frost, if not clandestine visitations by little Jack himself, triggered the display of autumn colors endured for generations, including mine.

If only the truth were that simple. As foresters tell us, a perfect autumn color display depends on complicated actions and interactions inside and outside the tree that involve pigments, hormones, chemicals, genetic traits, sunlight, rainfall, site, soil conditions, temperature, and the length of daylight. For a start.

But first, why do deciduous trees drop their leaves? Jeffrey A. Simmons, an environmental scientist at Mount St. Mary's University in Emmitsburg, Maryland, had a concise explanation for me. "Leaf shedding was forced on deciduous trees if they wanted to survive winter," he said. Conifers are able to ignore snow, ice, and harsh cold because their leaves, or needles, have a small surface area and the cells contain an antifreeze, Simmons explained. Maples, oaks, birches, hickories, and such, on the other hand, have broad leaves that would be severely frost-damaged by repeated freezing and thawing.

All of those autumn leaves, naturally, were once various shades of green because of chlorophyll pigments that effectively mask any other color pigments present in the leaf cells throughout the long growing season. The job of chlorophyll is to take energy from the sun and use it to manufacture sugars—the carbohydrates trees need for growth and development—from carbon dioxide and water. Photosynthesis hard at work. Since chlorophyll breaks down in the process, it is constantly replenished until autumn approaches, bringing shorter days and cooler nights. As sugar production slows and the supply of chlorophyll dwindles, those hidden pigments begin to appear. These are the carotenoids (as in carrots) that reward us with the wide range of yellow, orange, and

brown hues.

The hardwood forests' reds and purples are a different story. Those colors materialize on the leaves of such trees and shrubs as red maples, red oaks, sweetgums, dogwoods, sumacs, and Virginia creepers because of pigments called anthocyanins, which often tint yellow leaves to varying degrees—and combine with carotenoids to produce even richer oranges, reds, and purples. We're told that trees produce more anthocyanins when stressed. Bright sunshine is said to enhance anthocyanin production and thus intensify color in autumn's "burning bushes" (Thoreau). But scientists really don't know all the reasons why some trees manufacture the red pigments and others don't, or why a particular maple's leaves will turn yellow one year and red the next. One theory suggests that red coloration acts as a sunscreen, protecting leaves from damaging rays as they begin to fade. Another idea is that red leaves confuse sap-sucking aphids that occasionally deposit eggs near yellow leaves. Other researchers, however, believe that red pigments attract animals that eat the berries of plants like sumac, spreading the seeds to other locations. Then there's speculation that anthocyanins, which are water soluble, help leaves retain moisture, such as during a drought.

One thing's for sure: Our autumn woods would be boring without those red leaves. And a fiery palette of all kinds of warm colors keeps tourists returning in October to states like Vermont, where it is estimated that leaf-peepers will spend more than $360 million this fall. Naturally, a lot of folks in New England and elsewhere are concerned that climate change will mute those colors. "Don't worry," says biologist Matthew Tallis at the University of Southampton in England. "Research suggests that there may be an even more impressive display of fall color in the not-too-distant future."

Tallis participated in a recent two-continent study to determine how deciduous forests will respond to a significant increase in atmospheric carbon dioxide, the main driver of global warming. Experiments were set up in Wisconsin and in Italy to expose poplar and aspen forest canopies to a 45 percent increase in CO_2, the level predicted for the year 2050. Southampton researchers used an aircraft to measure color changes in the forest canopy in Italy and analyzed individual leaves. They estimated that autumnal senescence would be delayed 10 to 15 days independent of any temperature changes. "There was also strong evidence that those leaves were producing more anthocyanins," Tallis added. "There will be

no end to the glorious fall color."

But what about the impact of global warming, not just higher CO_2 levels, on autumn foliage? The University of Vermont's Proctor Maple Research Center, on the western slope of Mount Mansfield, is launching a three-year study this fall in which groups of sugar and red maple seedlings will be subjected to a range of temperatures in laboratory and natural settings. "We want to figure out whether cold nighttime temperatures are important in triggering anthocyanin production," says plant researcher Abby van den Berg. "If so, what will red leaf displays be like in the warmer autumns of the future?"

Then there's the matter of dramatic shifts in forest composition in the Northeast by the year 2100. In June the White House released a comprehensive new report, "Global Climate Change Impacts in the United States," with no-nonsense text and vivid graphics that ought to frighten a Hummer lover into buying a Fiat. By late this century, for example, residents of New Hampshire could experience a summer climate similar to the weather in North Carolina today. And the New England sugarbush could be a memory, today's maple-beech-birch forest having been replaced with the oak-hickory forest regime of the Allegheny Mountains.

It all depends on which of several emissions scenarios you're looking at, for there are computer models that map the future distribution of nearly every tree in North America based on atmospheric CO_2 concentrations. In a lower carbon-emissions scenario, maples and birches will still dominate hardwood forests in New York and New England in 2100—but the spruce-fir forest of northern Maine will be gone. Moreover, I've been told by a prominent forest ecologist that in any setting, the pace of forest change will be rather glacial. Many of the species that make up the northern hardwood forest canopy, he pointed out, can live for several hundred years, like my big maple. And their seedlings and saplings are able to survive in the understory for decades. Plus, the migration of new species, particularly shade-tolerant trees, tends to be slow.

Anyway, fall color in an oak-hickory forest is pretty darn dramatic. The flaming leaves of scarlet oaks and tupelos rival those of red maples, and the golden yellow of hickories would moderate somewhat the loss of sugar maples.

For now our deciduous trees have another trick up their branches. By summer's end their green leaves hold

concentrations of nutrients that were built up during the growing season: potassium, sodium, magnesium, iron, nitrogen, phosphorus, and others. "Losing those minerals would be a huge setback to the health of the tree," Jeffrey Simmons said. So evolution worked more magic. When trees begin to shut down for winter, they use a process called retranslocation to scavenge as many of those nutrients as possible from their leaves, storing them in woody tissue where they will be put to use building new growth the following spring. Meanwhile, layers of cork cells form to eventually close the microscopic pipelines between twigs and leaves, whose fragile veins scarcely hold them to the tree until they yield to gravity or break loose in wind and rain.

And fall and fall and fall in uncountable numbers. "It is pleasant to walk over the beds of these fresh, crisp, and rustling leaves," Thoreau wrote. "How beautifully they go to their graves! How gently lay themselves down and turn to mould! Painted of a thousand hues, and fit to make the beds of us living." However, it is possible to calculate their total weight, or mass. For example, the annual leaf-fall mass in a mature mixed hardwood forest in the Allegheny Mountains of West Virginia ranged from 1.57 to 2.45 tons per acre during the first 19 years of an ongoing study led by U.S. Forest Service soil scientist Mary Beth Adams. "It varies a lot from year to year, depending on rainfall, temperature, and insect outbreaks," she told me, adding that the long-term average was 1.83 tons an acre. That's a whole lot of spent foliage, for as Robert Frost wrote in his poem "Gathering Leaves," *Spades take up leaves, / No better than spoons, /*
And bags of leaves, / Are light as balloons.

Those statistics come from an especially verdant watershed in the Fernow Experimental Forest near Parsons, in north-central West Virginia. As Adams noted, the primeval forest was logged in 1910 toward the end of a clear-cutting orgy that began around 1880. That's when a peculiar steam locomotive called a Shay, a thunderous, belching machine that could climb steep mountain grades and haul incredibly heavy loads of timber, arrived in the Alleghenies. Now a century old, this second-growth stand is dominated by imposing sugar and red maples, American beeches, northern red oaks, and sweet birches, with a sprinkling of black cherries and soaring tulip poplars.

Her project's goal has been to determine whether acid rain is affecting the productivity of deciduous woodlands in the Alleghenies. (So far they're seeing that there is no change in productivity in the trees, but there are changes to soil and

water chemistry from acid rain.) And total leaf area is a good indicator of a forest's health. "We can easily estimate this by measuring the yearly leaf shed," Adams explained. To that end, three-foot-square litterfall traps were randomly placed in the Fernow Forest study areas. In autumn fallen leaves are bagged about once a week, dried in the laboratory, and weighed. Leaf fall in two 40-year-old forest stands, the scientist noted, was significantly lower.

So to extrapolate, in a really good year nearly 250 tons of dead leaves—a mere fraction of their weight when green and heavy with water—could accumulate beneath 100 acres of old hardwood forest. The litter won't go to waste. Though faded and crackly underfoot, the leaves still contain nutrients that the trees were unable to recover before leaf fall. So soil decomposers—bacteria and fungi—get to work, extracting a little energy for their own use and releasing the rest of the minerals into the earth, to be absorbed by the trees' roots. In the end, Jeffrey Simmons related, some deciduous trees will recover about 95 percent of the nutrients from their foliage through the processes of retranslocation and absorption, giving them a substantial head start on the next growing season. "If society could recycle like that," he added, "earth would be much better off."

Of course, this last step in nutrient recycling doesn't happen on the shaded front lawns of America, where leaves are an annual nuisance, to be exorcised at whatever cost. Home owners often cringe when falling leaves drift by the window, and the peace is soon disturbed by the decibels from all sorts of leaf blowers, from a $30 handheld electric model to the $630 wheeled, gas-powered Billy Goat, claimed to be the world's most powerful.

Naturally, all of these leaves—raked, blown, bagged, or piled—have to go somewhere. For example, Virginia's Fairfax County (outside Washington, D.C.) budgeted $2,315,676 for three rounds of street-side vacuum leaf collection this fall "to enhance the county's aesthetic environment." Home owners and businesses in 34 "leaf districts" pay a collection levy based on real estate values. The leaves are hauled to other counties for composting.

It was simpler when I was a youngster. All you needed to dispose of leaves was an old-fashioned iron rake and a few strike-anywhere matches. I grew up in the 1940s in a village in western Michigan where sugar maples had been planted along the arrow-straight streets early on, three of

them in front of our house with an elm off to the side. Raking the lawn every weekend in October and early November was a pleasure, not a chore, for it meant tussles in the leaf piles with the tomboy from next door and bonfires with roasted marshmallows on jackknife-sharpened willow sticks. Plus fireworks. Is there a lad today who knows that the shiny brown seeds of the spreading horsechestnut tree, when pried from their spiny husks and tossed into a blazing leaf pile, will explode like cherry bombs?

And then there was the wonderfully sweet aroma of burning leaves that wafted over our town long before "the environment" became a buzzword and the practice was declared a health hazard. Open leaf burning, the Environmental Protection Agency warns, "produces particulate matter and hydrocarbons, which contain a number of toxic, irritant carcinogenic (cancer-causing) compounds. Leaf smoke also contains carbon monoxide." Many communities ban the practice.

At our place we leave our leaves along the creek bank, where they will be washed downstream in the next torrent. I'm pretty sure that's okay. But I confess: Whenever I see smoke drifting up from a burning mound of leaves in the hamlet down in the valley, I follow the column to its source to savor the perfume—but not inhale. And to remember a time in my youth when hunting squirrels with my trusty lever-action .22 was more or less an excuse to spend golden afternoons deep in an oaky wood, heading home as a reddish Hunter's Moon, looking larger than life, lifted over the horizon.

I admit to taking a fat bushytail now and then for my mother's stew pot. Hard not to. As Thoreau observed, "So many [leaves] have fallen in the woods that a squirrel cannot run after a falling nut without being heard." But it was really a kid's best time of the year for discoveries: the wood thrush nest filled with beech leaves, golden-crowned kinglets calling *see-see-see* in the treetops, a red maple leaf impaled on a spiny burdock, last summer's fox den, a camouflaged woodcock that I nearly stepped on, leaves of multiple hues swirling down a creek, and the most majestic whitetail buck I've ever seen, munching acorns only a few yards away.

At the end of his lecture on "Autumnal Tints," Thoreau implored his Lynn audience to "let your walks now be a little more adventurous." I'd like to second that thought. Leaf-peepers ought to park their rides at a trailhead and venture, if only briefly, beyond the forest's edge. For

there's far more to contemplate at this glorious time of year than just "the color."

FOR MORE INFORMATION
To track the changing colors in your area, check out Yankee Foliage for a calendar estimating when leaves will change in New England, and the U.S. Forest Service and Weather.com for a guide to changing colors across the country.

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