



## The Glory of Leaves

Sometimes a masterwork hangs in a museum. Other times it hangs from the branch of a tree or rounds out a slender stem.

By Rob Dunn

**We have all held leaves**, driven miles to see their fall colors, eaten them, raked them, sought their shade. Since they are everywhere, it's easy to take them for granted.

But even when we do, they continue in their one occupation: turning light into life. When rays of sunlight strike green leaves, wavelengths in the green spectrum bounce back toward our eyes. The rest—the reds, blues, indigos, and violets—are trapped. A leaf is filled with chambers illuminated by gathered light. In these glowing rooms photons bump around, and the leaf captures their energy, turning it into the sugar from which plants, animals, and civilizations are built.

Chloroplasts, fed by sun, water, carbon dioxide, and nutrients, do the leaf's work. They evolved about 1.6 billion years ago when one cell, incapable of using the sun's energy, engulfed another cell—a cyanobacterium—that could. That cyanobacterium became the ancestor of every living chloroplast. Without their chloroplasts plants would be left like the rest of us, to eat what they find. Instead they hold out their green palms and catch light. If there is magic in the world, surely this is it: the descendants of tiny creatures in leaves, capable of ingesting the sun.

If you gather a bouquet of leaves to consider their magic, it is hard to overlook their diversity and, if you are the curious sort, to wonder why there exists such a preponderance of forms. Some leaves don't seem to be leaves at all, having become flower petals, thorns, or the spines on a cactus. But even an ordinary oak leaf, dandelion leaf, and grass blade differ in size, thickness, shape, hue, texture, taste, and nearly every other feature.

Leaves are large, small, thick, thin, compound, simple, curved, or lobed. And these terms just begin to describe the differences botanists have tried to catalog in their rich poetry of obscure adjectives—pinnate, ciliate, barbellate, bearded, canescent, glabrous, glandular, viscid, scurfy, floccose, arachnoid, and my favorite, tomentose (covered with woolly hairs). But putting the variety of structures aside, most leaves do essentially the same thing: They exist in the main to hold chloroplasts aloft. How can so many different geometries all perfectly capture the sun?

The work of natural selection offers a key to the puzzle. Desert leaves tend to be small, thick-skinned, waxy, or spiny, just like leaves in salty regions or other harsh lands—clear examples of the relatively few ways evolution can deal with a lack of water. Rain forest plants often have narrow leaves, with long, thin “drip tips,” to drain away excess water. In cold places one finds leaves with teeth—like birches and cherries—though why this particular pattern exists is the subject of debate.

Some of the most extreme examples of the way natural selection shapes leaves can be found at high elevations in the tropics, where nights are consistently cold and damp and the days hot and dry. Scramble high enough above the tree line in the mountains of Africa, Asia, Hawaii, and the Americas, and you will see thick towers of plants crowned by mops of living and dead leaves.

In a poetic moment botanists named these lovely circular leaf arrangements “giant rosettes.” The thick living leaves of these rosettes shelter new buds. They're hairy too, which adds insulation. The dead leaves help the plants withstand freezing at night and, simultaneously, save the night's cold dew for the dry day. Remove those decaying leaves from rosettes at high elevations and the plants can freeze to death, naked without their dead-leaf fur.

In many environments natural selection tends to favor a limited number of similar forms again and again, given the genes it has to work with. Sometimes there really does seem to be just one or a few best ways to deal with a particular set of conditions. If rosettes are not convincing, consider the meat-eaters.

In nutrient-poor bogs, plants have repeatedly turned to animals to supplement what the soil alone cannot provide. They have evolved rolled leaves, sticky hairs, mucous pools, or snap traps, all for capturing live prey. A bog is a terrifying place to be a fly.

But if climate and nutrient availability were the only explanations for leaf diversity, all of the leaves in a particular environment—a desert, a mountaintop, your backyard—would tend to be the same. Of course they are not. Many of the qualities of the leaves in your yard or salad are due to the limits of genes and time. Not all plants have the genetic variation it takes to become, under the natural selection imposed by desert conditions, a cactus. Conditions change. Species move. Every leaf is a work in progress. One suspects, for example, that leaves are evolving now to deal with the conditions in cities—pollution, drought, intense heat, and animal waste—but it may require more generations for natural selection to stumble, death by death, upon the more successful forms.

Other specific traits may have to do with the battles that have gone on among plants each day for more than 400 million years. Plants fight for nutrients and water in the soil, and they fight for sunlight in the canopy. Competition is why trees grow tall, stems become trunks, and forests grow dense. Trees have evolved in the struggle of plant against plant many times, in vastly different lineages. The highest leaves win, and so trees tend to evolve to be as tall as possible, given the limits of physics and precipitation. Without competition, every forest would be a thick film of green life.

The battles among plants have changed their stems and their veins. Leaves with more veins can carry more water to the chloroplasts, allowing the chloroplasts to make more sugar and the plants to grow faster. These species in turn can hold their leaves aloft to occupy more space in the sky and consume more sunlight before others get to it. Through time the plants that were able to produce more and more veins in their leaves won many battles and some wars.

Leaves with densely branched patterns of veins are also able to grow more quickly. The veins of a maple leaf, for instance, are like the roads of a city; they go everywhere and often intersect. They traffic in nutrients and water. The maple leaf can quickly get what it needs to continue to feed from the sun. Other leaves are not so lucky. Amid the seething competition for space in tropical forests, pity the single-veined leaf.

Plants have more to cope with than competition from other plants. The evidence of animals eating leaves is almost as ancient as the evidence for leaves themselves. In fossil dinosaur poop one finds evidence of ancient leaves. In fossil leaves one finds the holes made by ancient mouths. Nothing on life's menu is more popular. Moths, butterflies, beetles, fungi, monkeys, sloths, and great loping monsters like cows, bison, and giraffes eat the hard-earned greenery of plants, which, for all of their ingenuity, have never figured out how to run away.

So leaves resort to self-defense. Some plant leaves have become specialists in deadly tricks. Grass blades evolved the ability to accumulate the silica from the soil—becoming like tiny glass slivers, which ruin the teeth of browsers like cows one bite at a time. Other plants use chemicals to make themselves unpalatable or even poisonous. Sometimes the weapons are visible: latex oozing out of a vein or tingly hairs projecting from leaf blades. Other times they lurk unseen, waiting for the unsuspecting victim, be it the larva of a moth or an indiscriminating sheep.

Climate, competition, defense—these evolutionary saws and scissors can explain much of the diversity of leaves. Yet if you pick up two leaves in your backyard, most of what differs between them—the details naturalists have spent thousands of years naming—remains unaccounted for. Evolution can whittle similar forms again and again when confronted with similar circumstances. But through innovation and chance, evolution can also work in the abstract: Jackson Pollock dashing paint on the canvas of life. We should not expect to understand every tomentose blade or arachnoid lobe. Sometimes it is enough to step back and know a masterwork when we see one, whether it hangs in a museum or from its petiole on the branch of a park tree. Not that leaves care whether you notice; the blessing they convey comes each day with the rise of the edible sun.

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Rob Dunn's most recent book is *The Wild Life of Our Bodies*. Illustrations are from *Impressions of Nature: A History of Nature Printing*, by Roderick Cave.

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