# The Big Bloom How Flowering Plants Changed the World

Read a National Geographic magazine article about how flowering plants appeared during the Cretaceous period and get information, facts, and more about the flowers and the prehistoric world.

In 1973 sunflowers appeared in my father's vegetable garden. They seemed to sprout overnight in a few rows he had lent that year to new neighbors from California. Only six years old at the time, I was at first put off by these garish plants. Such strange and vibrant flowers seemed out of place among the respectable beans, peppers, spinach, and other vegetables we had always grown. Gradually, however, the brilliance of the sunflowers won me over. Their fiery halos relieved the green monotone that by late summer ruled the garden. I marveled at birds that clung upside down to the shaggy, gold disks, wings fluttering, looting the seeds. Sunflowers defined flowers for me that summer and changed my view of the world.

Flowers have a way of doing that. They began changing the way the world looked almost as soon as they appeared on Earth about 130 million years ago, during the Cretaceous period. That's relatively recent in geologic time: If all Earth's history were compressed into an hour, flowering plants would exist for only the last 90 seconds. But once they took firm root about 100 million years ago, they swiftly diversified in an explosion of varieties that established most of the flowering plant families of the modern world.

Today flowering plant species outnumber by twenty to one those of ferns and cone-bearing trees, or conifers, which had thrived for 200 million years before the first bloom appeared. As a food source flowering plants provide us and the rest of the animal world with the nourishment that is fundamental to our existence. In the words of Walter Judd, a botanist at the University of Florida, "If it weren't for flowering plants, we humans wouldn't be here."

From oaks and palms to wildflowers and water lilies, across the miles of cornfields and citrus orchards to my father's garden, flowering plants have come to rule the worlds of botany and agriculture. They also reign over an ethereal realm sought by artists, poets, and everyday people in search of inspiration, solace, or the simple pleasure of beholding a blossom.

"Before flowering plants appeared," says Dale Russell, a paleontologist with North Carolina State University and the State Museum of Natural Sciences, "the world was like a Japanese garden: peaceful, somber, green; inhabited by fish, turtles, and dragonflies. After flowering plants, the world became like an English garden, full of bright color and variety, visited by butterflies and honeybees. Flowers of all shapes and colors bloomed among the greenery."

That dramatic change represents one of the great moments in the history of life on the planet. What allowed flowering plants to dominate the world's flora so quickly? What was their great innovation?

Botanists call flowering plants angiosperms, from the Greek words for "vessel" and "seed." Unlike conifers, which produce seeds in open cones, angiosperms enclose their seeds in fruit. Each fruit contains one or more carpels, hollow chambers that protect and nourish the seeds. Slice a tomato in half, for instance, and you'll find carpels. These structures are the defining trait of all angiosperms and one key to the success of this huge plant group, which numbers some 235,000 species.

Just when and how did the first flowering plants emerge? Charles Darwin pondered that question, and paleobotanists are still searching for an answer. Throughout the 1990s discoveries of fossilized flowers in Asia, Australia, Europe, and North America offered important clues. At the same time the field of genetics brought a whole new set of tools to the search. As a result, modern paleobotany has undergone a boom not unlike the Cretaceous flower explosion itself.

Now old-style fossil hunters with shovels and microscopes compare notes with molecular biologists using genetic sequencing to trace modern plant families backward to their origins. These two groups of researchers don't always arrive at the same birthplace, but both camps agree on why the quest is important.

"If we have an accurate picture of the evolution of a flowering plant," says Walter Judd, "then we can know things about its structure and function that will help us answer certain questions: What sorts of species can it be crossed with? What sorts of pollinators are effective?" This, he says, takes us toward ever more sensible and productive methods of agriculture, as well as a clearer understanding of the larger process of evolution.

Elizabeth Zimmer, a molecular biologist with the Smithsonian Institution, has been rethinking that process in recent years. Zimmer has been working to decipher the genealogy of flowering plants by studying the DNA of today's species. Her work accelerated in the late 1990s during a federally funded study called Deep Green, developed to foster coordination among scientists studying plant evolution.

Zimmer and her colleagues began looking in their shared data for groups of plants with common inherited traits, hoping eventually to identify a common ancestor to all flowering plants. Results to date indicate that the oldest living lineage, reaching back at least 130 million years, is Amborellaceae, a family that includes just one known species, Amborella trichopoda. Often described as a "living fossil," this small woody plant grows only on New Caledonia, a South Pacific island famous among botanists for its primeval flora.

But we don't have an Amborella from 130 million years ago, so we can only wonder if it looked the same as today's variety. We do have fossils of other extinct flowering plants, the oldest buried in 130-million-year-old sediments. These fossils give us our only tangible hints of what early flowers looked like, suggesting they were tiny and unadorned, lacking showy petals. These no-frill flowers challenge most notions of what makes a flower a flower.

To see what the first primitive angiosperm might have looked like, I flew to England and there met paleobotanist Chris Hill, formerly with London's Natural History Museum. Hill drove me through rolling countryside to Smokejacks Brickworks, a quarry south of London. Smokejacks is a hundred-foot-deep (30-meter-deep) hole in the ground, as wide as several football fields, that has been offering up a lot more than raw material for bricks. Its rust-colored clays have preserved thousands of fossils from about 130 million years ago. We marched to the bottom of the quarry, got down on our hands and knees, and began digging.

Soon Hill lifted a chunk of mudstone. He presented it to me and pointed to an imprint of a tiny stem that terminated in a rudimentary flower. The fossil resembled a single sprout plucked from a head of broccoli. The world's first flower? More like a prototype of a flower, said Hill, who made his initial fossil find here in the early 1990s. He officially named it Bevhalstia pebja, words cobbled from the names of his closest colleagues.

Through my magnifying glass the Bevhalstia fossil appeared small and straggly, an unremarkable weed I might see growing in the water near the edge of a pond, which is where Hill believes it grew.

"Here's why I think it could be a primitive flowering plant," said Hill. "Bevhalstia is unique and unassignable to any modern family of plants. So we start by comparing it to what we know." The stems of some modern aquatic plants share the same branching patterns as Bevhalstia and grow tiny flower buds at the ends of certain branches. Bevhalstia also bears a striking resemblance to a fossil reported in 1990 by American paleobotanists Leo Hickey and Dave Taylor. That specimen, a diminutive 120-million-year-old plant from Australia, grew leaves that are neither fernlike nor needlelike. Instead they are inlaid with veins like the leaves of modern flowering plants.

More important, Hickey and Taylor's specimen contains fossilized fruits that once enclosed seeds, something Hill hopes to find associated with Bevhalstia. Both plants lack defined flower petals. Both are more primitive than the magnolia, recently dethroned as the earliest flower, although still considered an ancient lineage. And both, along with a recent find from China known as Archaefructus, have buttressed the idea that the very first flowering plants were simple and inconspicuous.

Like all pioneers, early angiosperms got their start on the margins. In a world dominated by conifers and ferns, these botanical newcomers managed to get a toehold in areas of ecological disturbance, such as floodplains and volcanic regions, and adapted quickly to new environments. Fossil evidence leads some botanists to believe that the first flowering plants were herbaceous, meaning they grew no woody parts. (The latest genetic research, however, indicates that most ancient angiosperm lines included both herbaceous and woody plants.) Unlike trees, which require years to mature and bear seed, herbaceous angiosperms live, reproduce, and die in short life cycles. This enables them to seed new ground quickly and perhaps allowed them to evolve faster than their competitors, advantages that may have helped give rise to their diversity.

While this so-called herbaceous habit might have given them an edge over slow-growing woody plants, the angiosperms' trump card was the flower. In simple terms, a flower is the reproductive mechanism of an angiosperm. Most flowers have both male and female parts. Reproduction begins when a flower releases pollen, microscopic packets of genetic material, into the air. Eventually these grains come to rest on another flower's stigma, a tiny pollen receptor. In most cases the stigma sits atop a stalk-like structure called a style that protrudes from the center of a flower. Softened by moisture, the pollen grain releases proteins that chemically discern whether the new plant is genetically compatible. If so, the pollen grain germinates and grows a tube down through the style and ovary and into the ovule, where fertilization occurs and a seed begins to grow.

Casting pollen to the wind is a hit-or-miss method of reproduction. Although wind pollination suffices for many plant species, direct delivery by insects is far more efficient. Insects doubtless began visiting and pollinating angiosperms as soon as the new plants appeared on Earth some 130 million years ago. But it would be another 30 or 40 million years before flowering plants grabbed the attention of insect pollinators by flaunting flashy petals.

"Petals didn't evolve until between 90 and 100 million years ago," said Else Marie Friis, head of paleobotany at the Swedish Natural History Museum on the outskirts of Stockholm. "Even then, they were very, very small.

A thoughtful woman with short brown hair and intense eyes, Friis oversees what many experts say is the most complete collection of angiosperm fossils gathered in one place. The fragile flowers escaped destruction, oddly enough, thanks to the intense heat of long-ago forest fires that baked them into charcoal.

Friis showed me an 80-million-year-old fossil flower no bigger than the period at the end of this sentence. Coated with pure gold for maximum resolution under an electron microscope, it seemed to me hardly a flower. "Many researchers had overlooked these tiny, simple flowers," she said, "because you cannot grasp their diversity without the microscope."

So we squinted through her powerful magnifier and took a figurative walk through a Cretaceous world of tiny and diverse angiosperms. Enlarged hundreds or thousands of times, Friis's fossilized flowers resemble wrinkled onion bulbs or radishes. Many have kept their tiny petals clamped shut, hiding the carpels within. Others reach wide open in full maturity. Dense bunches of pollen grains cling to each other in gnarled clumps.

Sometime between 70 and 100 million years ago the number of flowering plant species on Earth exploded, an event botanists refer to as the "great radiation." The spark that ignited that explosion, said Friis, was the petal.

"Petals created much more diversity. This is now a widely accepted notion," Friis said. In their new finery, once overlooked angiosperms became standouts in the landscape, luring insect pollinators as never before. Reproduction literally took off.

Interaction between insects and flowering plants shaped the development of both groups, a process called coevolution. In time flowers evolved arresting colors, alluring fragrances, and special petals that provide landing pads for their insect pollinators. Uppermost in the benefits package for insects is nectar, a nutritious fluid flowers provide as a type of trading commodity in exchange for pollen dispersal. The ancestors of bees, butterflies, and wasps grew dependent on nectar, and in so doing became agents of pollen transport, inadvertently carrying off grains hitched to tiny hairs on their bodies. These insects could pick up and deliver pollen with each visit to new flowers, raising the chances of fertilization.

Insects weren't the only obliging species to help transport flowering plants to every corner of the Earth. Dinosaurs, the greatest movers and shakers the world has ever known, bulldozed through ancient forests, unwittingly clearing new ground for angiosperms. They also sowed seeds across the land by way of their digestive tracts.

By the time the first flowering plant appeared, plant-eating dinosaurs had been around for a million centuries, all the while living on a diet of ferns, conifers, and other primordial vegetation. Dinosaurs survived for another 65 million years, and some scientists think this was plenty of time for the big reptiles to adapt to a new diet that included angiosperms.

"Just before the dinosaurs disappeared, I think a lot of them were chowing down on flowering plants," says Kirk Johnson of the Denver Museum of Nature & Science. Johnson has unearthed many fossils between 60 and 70 million years old from sites across the Rocky Mountain region. From them he deduces that hadrosaurs, or duck-billed dinosaurs, subsisted on large angiosperm leaves that had evolved in a warm climatic shift just before the Cretaceous period ended. Referring to sediments that just predate the dinosaur extinction, he said, "I've only found a few hundred samples of nonflowering plants there, but I've recovered 35,000 specimens of angiosperms. There's no doubt the dinosaurs were eating these things."

Early angiosperms were low-growing, a fact that suited some dinosaurs better than others. "Brachiosaurs had long necks like giraffes, so they were poorly equipped for eating the new vegetation," says Richard Cifelli, a paleontologist with the University of Oklahoma. "On the other hand ceratopsians and duck-billed dinosaurs were real mowing machines." Behind those mowers angiosperms adapted to freshly cut ground and kept spreading.

Dinosaurs disappeared suddenly about 65 million years ago, and another group of animals took their placethe mammals, which greatly profited from the diversity of angio-sperm fruits, including grains, nuts, and many vegetables. Flowering plants, in turn, reaped the benefits of seed dispersal by mammals.