Artists join paleobotanists to bring ancient plants to life—and pique viewer interest

Carolyn Beans, Science Writer

No one has ever seen a living Czekanowskia, an extinct gymnosperm that grew in forests across the Northern Hemisphere from around 210 through 100 million years ago. So before attempting to paint a picture of this ancient plant, Marlene Hill Donnelly built her own.

Donnelly, a paleoartist at the Field Museum in Chicago, IL, consulted with paleobotanists, examined fossils, and studied work by other paleoartists. She shaped foil and wire into branches and leaves with lobes so narrow that they resembled pine needles, aiming to highlight plants alongside dinosaurs. This painting shows water pooled in a *Tyrannosaurus rex* footprint with fallen leaves strewn beside a magnolia-like blossom. The puddle reflects leafy trees, as well as a *T. rex*—a juxtaposition meant to emphasize the importance of flora and not just fauna. Image credit: Julius Csotonyi, Smithsonian Institution.

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though finer. Donnelly then made a sketch based on her model and thought to herself, “Hmm, maybe not.” To truly capture its form, she needed more information. “I seriously hate making things up,” she says.

Donnelly is one of a number of paleoartists working closely with paleobotanists to paint prehistoric plants with as much accuracy as fossil records—and some clever experimentation—allow. Paleobotanists provide volumes of information to reconstruct a single plant. But before the brush hits the canvas, artists sometimes ask questions that send scientists searching for more data. “Scientists and artists go backwards and forwards constantly, to try and work out what that final image is going to look like,” says paleobotanist Ian Glasspool, a research associate at Colby College in Waterville, ME.

In doing so, these teams resurrect not only individual plants but also the plants’ central roles in past ecosystems. They boost both precision and awareness. Reconstructed, reimagined images of dinosaurs, for example, oftentimes don’t include much in the way of accurately portrayed vegetation—if they include any vegetation at all. These scholars are filling in the greenery to help themselves, and the public, truly see ancient plants.

**A Simple Question**

Czekanowskia is only one of dozens of plants that Donnelly modeled in wire and foil and then painted in collaboration with Glasspool and paleobotanist Jennifer McElwain of Trinity College Dublin, Ireland. In the 2000s, while working at the Field Museum, McElwain and Glasspool collaborated with an international team to unearth fossilized plants from East Greenland. Today, the terrain is frozen tundra. But the leaves that Glasspool and McElwain collected drifted to the ground before the landmass had shifted so far northward and while the climate was tropical. The expedition’s aim was to capture changes in ecology before, during, and after a mass extinction event—likely caused, in part, by global warming—at the end of the Triassic and the beginning of the Jurassic periods.

Donnelly’s initial role was to create a painting of each plant for scientific documentation, and then situate them digitally into a mural to offer Field Museum visitors a portal into the Late Triassic. “It became obvious that [the collaboration] was so much more,” says McElwain. "The questions going back and forth between us were not just a communication. It was also research.”

An artist depicts a plant called Pleuromeia thriving amongst an animal called a Lystrosaurus about 250 million years ago. The scene is meant to illustrate the low biodiversity in the aftermath of the End-Permian extinction. Image credit: Hannah Bonner/National Geographic Kids.
One of the first questions Donnelly asked was what color green were the plants. “This question in itself is such a basic artistic question, but one that I imagine few paleobotanists even consider, let alone attempt to answer,” says Glasspool.

At first, McElwain thought the question was impossible to answer. Then she thought more about it. She knew that the leaves of evergreen trees tend to be dark, and that leaves with high leaf mass per area tend to be evergreen. She couldn’t calculate leaf mass from fossils, but by slicing fossil leaves into thin sections, she and her team could measure cuticle thickness, which worked as a proxy (1). “We were able to say, ‘OK we think this was deciduous so it should be on the brighter greens and we think this was evergreen so it should be on the bluer green hues,’” she says.

The collaborative process from McElwain, Glasspool, and Donnelly, described in their recent book, Tropical Arctic, makes one thing clear: Resurrecting whole plants from the fossil record is no easy task (2). Fossilized plants are typically scattered in pieces with a bit of leaf here, a flower there. Plant fossils are also often found as flattened compressions, revealing little of how gracefully a leaf would have draped from a branch.

In the case of Czekanowskia, says Donnelly, “they are big, hand-sized leaves, but very, very delicate.” Previous reconstructions, her own first attempt included, showed the leaves sticking straight up. She wasn’t convinced that posture was likely.

Donnelly consulted with three mechanical and civil engineers in her family for advice on how to illuminate what sort of leaf positioning might have been possible. With their guidance, she attached tiny weights to the tips of Gingko leaves—likely the closest modern-day relative—and measured how deeply they bent. She then tested various papers and metal foils to find a material that bent the same way with the same weight attached. Donnelly made a model

Reconstructed based on fossils, this is an artist’s conception of Thaumatopteris brauniana, a large fern that existed at the Triassic-Jurassic boundary and thrived in the harsh conditions of the Jurassic. This carbon dust drawing is a prelude to a color rendering that appeared in the book Tropical Arctic. Image credit: Marlene Hill Donnelly (artist).
by cutting the closest match—copier paper—into the size and shape of Czekanowskia leaves. “They just drooped,” she says.

But most leaves bend slightly upward from either side of each vein. This folding gives a limp material greater strength. “Think paper airplanes,” explains Donnelly, who scored the paper where veins would be and watched as the limp form lifted, though only slightly. “It would have been biomechanically impossible for those things to stick straight up,” she says.

A More Complete Picture
The ultimate goal for many paleobotanists is to understand how ancient plants functioned as part of an ecosystem. Our ability to measure the ecology of plants transcends time, says McElwain. “If you can understand the ecological characteristics, you can make parallels with the past, today, and where we’re going in the future.”

At the Smithsonian’s National Museum of Natural History’s (NMNH) fossil hall in Washington, DC, an exhibit called “Deep Time” opened in 2019. Curators rigorously researched plants within the context of whole ecosystems to show visitors how flora and fauna interacted in natural communities. “We’re trying to really get people to think about how ecosystems work, and therefore we illustrated organisms in their context,” says paleobotanist Scott Wing, a research scientist and curator of fossil plants at the museum.

Vancouver, Canada-based scientific illustrator and paleoartist Julius Csotonyi, one of many artists who worked on the exhibit, digitally painted 59 pieces. His mural of an early rainforest includes palm trees in the genus Sabalites with aging leaves that form a skirt around the trunk. The reconstruction is based on fossils, but also on photographs of modern day relatives.

Wing and NMNH colleague Conrad Labandeira, a curator of fossil arthropods, also offered Csotonyi fossil evidence of hungry insects. “These leaves unfold in like a fan, and you have these little dots of damage that multiply out into more than one spot,” says Csotonyi. “I was able to put some of these into these images to make them even more accurate with respect to the ecology.”

Getting the ecology right also means positioning plants in realistic densities—a challenge because fossilized plants are often found far from where they rooted, says Mallorca, Spain-based natural science illustrator Hannah Bonner. “You have a bunch of remains that maybe all got washed together by a stream. That doesn’t tell you really what those plants looked like when they were vertical and how far apart they were.”

In one of many scenes that she’s contributing to her forthcoming exhibit at the University of California, Berkeley’s Valley Life Sciences Building, Bonner needed to depict a community of Pleuromeia, an extinct genus of lycophytes that grew as branchless, leaf-covered stems. To create the reconstruction, which originally appeared in one of her children’s books (3), Bonner worked closely with Berkeley scientists and exhibit cocreators Cindy Looy and Ivo Duijnstee. The researchers shared their expertise, Duijnstee’s own reconstruction of an individual plant, and scientific articles, including one that contained a photograph of Pleuromeia plants fossilized in three-dimensions. “You can see how far apart they were,” says Bonner (4).

The exhibit, expected to debut in 2022 in a 13-meter-long glass case, will take visitors back in time through major climatic changes. “The goal of the exhibit is to show how life influences the planet and how processes on the planet influence life,” explains Looy, who describes herself as a “plant ecologist who works in the past.”

The exhibit includes both realistic depictions and cartoon-like sketches. But even Bonner’s simplest drawings require “an enormous amount of research,” says Duijnstee, a paleobiologist and artist.

McElwain, Glasspool, and Donnelly ultimately produced three reconstructions of whole landscapes: a richly diverse Late Triassic, a species-poor earliest Jurassic transformed by climate change, and a diverse yet fundamentally different later Early Jurassic. McElwain and Glasspool used ecological sampling and statistical techniques to estimate how common each species would have been in each period. The paintings reflect those numbers.

Much discussion went into whether to place plants in standing water or upland, and alongside which other species. Donnelly scanned her paintings of individual plants—mostly crafted in traditional watercolor—so that she could digitally move them as scientists debated placement. Each reconstruction contained more than 500 individual components that she could resituate as needed.

In the Shadows of Dinosaurs
Paleoartists and the scientists they work with don’t always go to such lengths to capture prehistoric plants. In many reconstructions, dinosaurs rule over bare ground, a scene that paleobotanists refer to as the “dinosaur in a parking lot,” says Looy. “[The artists] know that grasses weren’t there as ground cover, so they don’t know what else to put down.”

Part of the challenge with plants is that there are so many different species to reconstruct in any given environment, says Donnelly. “We reconstruct [the dinosaur] and then we pull in all the plants, which takes about four times longer.” And in some ways, the fossil record for dinosaurs is more straightforward, she says. “We do have complete skeletons of the animals and people who know what the muscle should have looked like.”

But all paleoart—whether portraying plants or animals—is to some degree conjecture, says Wing. “It’s a hypothesis of the way the world looked.” Wing believes that paleoartists often paint dinosaurs in greater detail simply because they care more about dinosaurs. “Everybody who works on plants has the desire to help the rest of the world understand the beauty and fascination of these creatures,” he says, adding that artists help illustrate them in ways that make them more comprehensible.
In the Deep Time exhibit, plants are intentionally placed at center stage in murals alongside dinosaurs. In a signpost explaining the Cretaceous period, one of Csotonyi’s paintings shows water pooled in a Tyrannosaurus rex footprint. Fallen leaves lay strewn alongside a magnolia-like blossom. The puddle reflects leafy trees, as well as a T. rex—albeit upside down. This positioning, “dethrones the king, so to speak,” says Csotonyi, who regularly reconstructs dinosaurs, including the T. rex images on US postal stamps (5). “No disrespect intended because he’s an impressive animal, but the plants were also huge stars of the show.”

Each ancient plant can be fascinating in its own right. But the progression of these plants through time tells a story that many paleobotanists and artists believe is critical for the public to hear. The NMNH, Berkeley, and Field Museum landscape reconstructions all capture periods when changes in climate had a dramatic impact on survival. Donnelly estimates that she spent 4,000 hours creating her mural of the Late Triassic. Her next mural, depicting the aftermath of the Triassic–Jurassic extinction event, came together faster, simply because there were far fewer species to reconstruct.

With these and other efforts, dinosaurs in parking lots are becoming less common. “You’ve had a few leaders in the field who did a spectacular job of introducing this [attention to plants] and guiding other paleoartists,” says Csotonyi, noting that the paleoartist and naturalist Jay Matternes, who painted murals for the previous NMNH fossil hall, inspired his own work. There’s a growing recognition that excluding plants in these reconstructions “was just ridiculous,” says Donnelly. Plants, says Bonner wryly, “are not just the things that get eaten.”

1 W. K. Soh et al., Palaeo leaf economics reveal a shift in ecosystem function associated with the end-Triassic mass extinction event. Nat. Plants 3, 17104 (2017).
2 J. C. McElwain, M. Hill Donnelly, I. J. Glasspool, Tropical Arctic (The University of Chicago Press, 2021).
3 H. Bonner, When Dinosaurs Dawned, Mammals Got Munched, and Pterosaurs Took Flight (National Geographic Kids, Washington, DC, 2012).
4 G. Fuchs, L. Grauvogel-Stamm, D. Mader, A remarkable in situ Pleuromeia and Anomopteris flora from the Middle Buntsandstein (Lower Triassic) of the Eifel (F. R. Germany) morphology, palaeoecology and palaeogeography. Palaeontogr. Abt. B 222, 89–120 (1991).
5 A. McDermott, Science and culture: Dinosaur art evolves with new discoveries in paleontology. Proc. Natl. Acad. Sci. U.S.A. 117, 2728–2731 (2020).