The rollercoaster of exploding pollen

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Credit: PLOS Blogs

When I think about reading peer-reviewed natural history papers—including contemporary articles in a *Natural History Miscellany Note* or the Scientific Naturalist section—I imagine them mostly as a classic throwback—just a scientist, a hand lens, and a notebook. I generally do not think about employing $50,000 of high-speed video recording equipment to test dueling hypotheses about pollination modes from the 1860s. I'm clearly missing out.

The *American Naturalist* recently published a mash-up of 19th century natural history observations and 21st century tech: in "Dispensing Pollen Via Catapult: Explosive Pollen Release in Mountain Laurel (Kalmia latifolia)" Dr. Callin Switzer and coauthors present speed records, specialized weaponry vocabulary, and plot twists.

The Speed Records: Mountain laurel is well known for its explosive pollination—a great botanical cocktail party conversation starter, but an adaptive function that has remained a mystery since the 19th century. Back in 2005 fans of understory plants of the temperate deciduous forest and speed records were wowed by bunchberry—researchers from Williams College clocked this explosive pollinator launching pollen grains at 3.1 meters/second, and accelerating pollen at 24,000 meters/second2.

Switzer's research at the most basic level sought to record the speed and acceleration of mountain laurel's explosive pollen. The mechanisms behind the explosion were well documented by the 1990s (pollen on the mountain laurel anthers are tucked into "pockets" in the petals and held under tension by curved filaments—when the anther is released from the pocket, the pollen is launched into the air), but the speed was still unrecorded. Switzer explains, "The paper was inspired by walking around the Arnold Arboretum with several of the faculty there. Robin Hopkins (my Ph.D. advisor) and Ned Friedman both knew that I had done some high-speed video projects in the past, and they suggested that I should take a look at the mountain laurels. I first had the high-speed videography background, and then Robin pointed me to the 19th century literature." From the high-speed videos, Switzerfound that mountain laurels launched pollen at 3.5 meters/second for an average maximum speed and achieved average maximum acceleration at 4,100 meters/second2. Mountain laurels thus have "one of the fastest-moving floral parts recorded"!

But why? In 1867 The *American Naturalist* published competing hypotheses for the adaptive function of explosive pollination in mountain laurels. Was the pollen aimed at the stigma for incredibly efficient self-pollination? Or is the pollen catapulted on to visiting bees for cross-fertilization? These 19th century natural history observations sat at the heart of Switzer's interest in quantifying the speed of mountain laurels—a chance to unravel this species' mythology of adaptive explanations. "I think of natural history as a part of biology that starts with curiosity about the natural world." Switzer reflects. "Naturalists tend to get ideas for projects simply by going out into the field with a hand lens and a notebook—with all the new technology available, however, naturalists can do a lot more interesting and quantitative studies."

Before revealing the speed-pollen's adaptive function, I just need to acknowledge the weird side effect of reading about explosive pollen—I learned a ton about the physics and vocabulary of medieval weapons…

Specialized Weaponry Vocabulary: The next time you are struggling to articulate the difference between a regular catapult and a medieval trebuchet, just think about the difference between a mountain laurel and a bunchberry. While both flowers have filaments under tension and fling pollen from the tips of their anthers, on bunchberry anthers there is a hinge connecting the anther to the filament tip. The bunchberry trebuchet is a specialized catapult: the payload is attached to the throwing arm by a hinge. Mountain laurels may be standard issue catapults—without the hinge that propels bunchberry pollen with incredible acceleration—but mountain laurel pollen grains are structurally designed to be their own weapon. The mountain laurel's pollen grains "form tetrads connected with viscin threads…causing each anther to release several stringy aggregations of pollen when it is triggered." Switzer hypothesizes that these stringy aggregations may act as a bola— hitting a target/pollinator and then wrapping around to attach itself tightly. Both the bunchberry and mountain laurel papers weaponize their flowers, making explosive pollination seem explicitly conflict-driven. I asked Switzer, "Are plants at war with their pollinators?" He responded, "plants and pollinators are in evolutionary conflict—they have different "goals", and both are constantly evolving to suit their own goals. If you'll excuse the anthropomorphizing, plants "want" bees to keep pollen on their bodies and transfer it among flowers, but bees "want" to collect the maximal amount of resources, without wasting energy carrying pollen among flowers." When we look closely at the world around us, the metaphors of natural harmony and balance blur and fade: petals are architects of secret triggers, flowers a minefield of exploding pollen.

The Plot Twists: Switzer filmed 69 mountain laurel pollen explosions outdoors at the Arnold Arboretum to capture the insect visitors and causes of catapulting pollen. Bees—mostly bumble bees—triggered the anther catapults, while appearing to search for nectar. During this fieldwork, and in the playbacks of the high-speed videos, Switzer watched pollen fly past the bees. It seemed like the catapults were missing their target. Maybe this was an elaborate, Rube Goldberg-esque set up to have a bee trigger a catapult to self-fertilize a flower via an extremely fast but weirdly complicated mechanism?

A second set of high-speed videos, recorded in the lab, allowed Switzer to calculate pollen trajectories in 3-D space. In these videos, the flower is set in profile to the camera and half the petals have been removed to give a clear view of the flower parts: stigma, style, anther pocket and filament. The catapult is manually triggered by a needle. When the pollen trajectories are traced and modeled into 3-D space, it's clear that most of the time the catapulted pollen crosses the central axis of the flower at just about bee-height.

Switzer says, "I was very surprised when I made observations with only my eyes, and I saw pollen flying past the bees. I came up with all kinds of interesting explanations in my head, until I collected the high-speed videos and saw what was really happening." In the Discussion of the pollen catapult paper, there is a refreshing transparency about this plot-twist moment: "Only with detailed experimentation and observations were we able to better understand the adaptive significance of explosive pollination—we realized that field-based observations did not allow us to see how much pollen actually hit the bee (because the bee's body often blocked the view)." The story of the research—stretching back to those 19th century naturalists and the mythology of adaptive explanations—is so clear here. We thought we saw something. We tested it from another angle and saw something else. As Switzer explains, "This was indeed a gut-check moment, and it did help me have more empathy for 19th century naturalists as well as present day naturalists. Doing good science with good statistics is hard—it can be so easy for scientists (myself included) to convince themselves of something that is not true. For me, it's really helpful to get constructive feedback from others to help me find those 'blind spots.'"

Switzer's ultimate contribution—beyond allowing mountain laurel to rest on its speed laurels, side by side with bunchberry in the Fast Plants Hall of Fame—is this effort to keep looking: to bring in two high speed cameras, half-dissected flowers in a lab setting, and 3-D modeling, and shed light on the blind spots with every tool in his 21st century natural history toolbox.

More information: Callin M. Switzer et al. Dispensing Pollen via Catapult: Explosive Pollen Release in Mountain Laurel (Kalmia latifolia), *The American Naturalist* (2018). DOI: 10.1086/697220

Joan Edwards et al. A record-breaking pollen catapult, *Nature* (2005). DOI: 10.1038/435164a