Our research seemed to be on the brink of catastrophic failure. "What do you mean the fruits aren’t growing??" I demanded of my Ph.D. student and long-time collaborator, Adam Hadley.

We had planned to conduct a study that examined how a well-known tropical herb (Heliconia tortuosa) survived in forest fragments surrounding Las Cruces. We already knew that its main floral visitor, the green hermit hummingbird (Phaethornis guy) was reluctant to cross pasture between forest fragments, and predicted that this should disrupt pollen flow for H. tortuosa, with potentially dire consequences for the plant’s reproduction. Now we were trying to hand pollinate this plant species as the perfect “baseline” against which to compare natural conditions. We expected to see decreased pollination in small, unconnected fragments. Such “pollen limitation” experiments have been done since before Gregor Mendel in the 1800s. Now, I was hearing from Adam that all of the hand pollinations we’d tried weeks earlier were showing no signs of causing fruit and seeds to grow. This result stood in stark contrast to the flowers that were left open for hummingbird visitation – which were overflowing with fruit (at least in the big forest patches like Las Cruces).

Luckily, we managed to find another effective method for assessing pollen limitation, but the...
problem of why we couldn’t hand pollinate this species lingered in our minds. Were we breaking the flower in some undetectable way when hand pollinating? Our collaborator from Smithsonian National History Museum, Dr. John Kress didn’t think so. Were hummingbirds bringing higher quality pollen than we were able to find? Or the far out possibility: were hummingbirds doing something to the plant to caused it to "turn on" and allow pollination? Walking by the enclosed greenhouses one day it occurred to me that we could distinguish these hypotheses by simply catching hummingbirds, cleaning them of extraneous pollen, and then releasing them into an aviary where we would hand pollinate as before.

The following year, our indomitable field assistants – Mao Panagua and Esteban Sandi (“Tocho”) helped us to erect an aviary at the bottom of the garden out of bamboo and shade cloth. We captured hummingbirds and cleaned them of any pollen to exclude the possibility that certain species were bringing in different qualities of pollen. We pollinated the herbs ourselves with one exposed flower in each aviary, and released the hummingbirds to see if their contact with the herb would result in fertilisation. Excitingly, the first experimental data showed that the simple act of green hermit hummingbird visitation ‘turned on’ the flowers we had hand pollinated. As our sample size grew, this effect remained, but with the interesting twist: only two hummingbird species – the green hermit and violet sabrewing (Campylopterus hemileucurus) were capable of doing this. Other species we introduced to the aviary including the rufous hummingbird (Amazilia tzacatl), scaly-breasted hummingbird (Phaeochroa cuvieri) and the green-crowned brilliant (Heliodaxa jacula) were nearly as poor as we had been in our initial failed pollen limitation experiments. The plant really seemed capable of distinguishing between hummingbird species, and knowing which to respond to.

To our knowledge, this was the first time such plant ‘behaviour’ had been observed in nature. But this result begged for more information. We needed to find out how such recognition could occur. We spent nearly a year thinking of the possibilities. Could the answer be explained by different species causing different vibrations from their wing-beat speeds? Could chemical cues caused by hummingbird saliva indicate the correct species to the herb, or what about the mites carried by the birds? We were confronted by a dizzying array of possibilities, and I must admit that a few of our preliminary experiments were a bit ‘out there’, and were a tad embarrassing even at the time. At one point we found ourselves holding vibrating electric toothbrushes up to flowers to see if this induced pollination. The things you do for science.

Eventually we converged on the most likely possibility – that the amount of nectar extracted from the flower allowed the plant to make the choice. We already knew that the green hermit and the violet sabrewing, the two ‘successful’ pollinators, had much longer and more curved bills than the other species. Could this result in more nectar extracted and a subsequent ‘switch in
the plant? To test this idea we first conducted an extensive study of how much nectar each hummingbird species removed. Sure enough, long-bills did better than short ones. Next, we did the critical experiment: nectar extraction and hand pollination. If nectar extraction by hummingbirds was the cue for ‘turning on’, human extraction of nectar should enable our hand pollinations to work.

When viewed under an epifluorescence microscope, the tracks made by pollen as it germinates and moves toward the plant ovary make beautiful glowing green tracks through the flower style. These ‘pollen tubes’ are therefore an indication of whether or not a plant has been successfully pollinated. To our surprise - and relief that there would be no more weird toothbrush scenarios - these nectar extraction experiments resulted in styles that glimmered with pollen tubes – in contrast to styles for which we didn’t extract nectar, where styles were as black as a cloudy night sky.

But why would a plant bother to recognise pollinators, and how could such a bizarre behaviour evolve? As any biologist knows, one of the main points of sexual reproduction is to enable new genetic mixtures to occur – which enables adaptations to a changing environment and usually results in higher offspring fitness. On the other hand, inbreeding with highly related individuals often allows deleterious mutations to persist in a population. As any parent knows, reproduction is expensive. Food, education, car repair bills – just to name a few.

Plants also seek to avoid inbreeding, and try to minimise the costs associated with reproduction. It would be highly beneficial to a plant if it could avoid investing in costly seeds and fruit when ‘inbred’ pollen is deposited, but to invest when ‘good’ pollen from further away arrives. If you bother to make a seed and fruit every time you get pollen, it is a substantial energy expenditure; you could be making a seed from your siblings’ genes. If you make a seed or fruit only from distant, high-quality pollen, it could be an adaptive advantage. We knew from our radio-telemetry data that straight-billed hummingbird species (that couldn’t turn on the plant) tend to move only short distances on a daily basis, thereby likely bringing mostly inbred pollen. On the other hand, the curve-billed species move long distances – up to 2.5 km daily. A closer look at our data showed a strong correlation between the capacity of a hummingbird species to ‘turn on’ the plant and the median distance it travels! So H. tortuosa appear to recognise and ‘turn on’ for pollinators that are likely to be bringing pollen from distant neighbours – which are less likely to be relatives.

So, we managed to snatch a minor victory from the jaws of what was nearly a major defeat. We are well aware of multiple examples of how animals and plants have co-evolved and become adapted to one another, but often the mechanisms behind these co-evolutionary relationships are harder to see. Animals often have impressive cognitive abilities that allow them to recognise and specialise on particular food sources, but this discovery indicates that plants may also be involved in these complex, ‘decision-making’ behaviours. We have managed to shed light on an occurrence that is, at least at this moment in scientific history, extremely unique. As is usually the case, still so many questions remain. How many other plant species show this behaviour? According to the Heliconia Society, few Heliconia species have...
been hand pollinated. Might this at least apply to the genus, containing more than 300 species?

A more complex question exists too: what are the implications for the conservation of plants and pollinators? Pollination webs are generally considered pretty robust to change; this is because most plants are quite generalised and accept many pollinators. If one pollinator crashes, there are still many others to take its place. In the case of H. tortuosa though, only two species bear most of the responsibility for its pollination, and our research has shown that these two species are both sensitive to forest loss and fragmentation. Will this specialisation by H. tortuosa ultimately result in its demise? Specialist species are often the most vulnerable to environmental changes; they have fewer buffer strategies into which they can retreat. For such species, forest landscape connectivity is key. Especially in environments like Las Cruces, in which tropical forests have been fragmented from development and agriculture. The unique and fascinating nature of this plant therefore means it will require careful management, but if we can maintain large, well connected patches in the landscape and beyond, then it does not have to spell disaster for this vibrant, and very picky, herb.