

The Specific Signals Plants Use to Attract Pollinators When Competition Is High

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Abstract

Pollination is, honestly one of the most critical ecological processes on Earth, because around 87.5% of all flowering plant species depend on animal pollinators for reproduction. Now, if several different plant species bloom at the same time and basically draw from the same pollinator crowd, competition gets intense, and the stakes for getting the “right” visitor rise quite a bit. To keep pollination coming in that kind of scenario, plants don’t rely on just one trick they use a sophisticated layered set of signals—things like visual cues, color, UV patterning, floral symmetry, even small shifts in shape and angle; then olfactory signals, volatile organic compounds that are tuned toward particular pollinators; and reward based messages, delivered through nectar chemistry and also the overall pollen quality. But it’s not only about individual signals. In lots of cases plants that are competing with neighbors can show character displacement, meaning they evolve floral traits that become more different in sympatry rather than in allopatry, mostly so they reduce pollinator overlap. Field experiments, meta-analyses, and chemical ecology work keep pointing to the same general idea: each channel has its own job. Visual cues are more about attracting from farther away, scent acts like a navigation tool that helps approach while also pushing species specificity, and reward quality decides whether the pollinator comes back. This article looks at each signal category in depth, it reviews how high competition tends to amplify and fine tune these traits, and it also considers broader consequences for plant evolution, speciation, and conservation, especially as pollinator populations keep declining.

Keywords: *floral signals, floral scent, character displacement, pollination syndromes, pollinator competition, nectar rewards, visual signals*

I. Introduction

Stand in a wildflower meadow in early summer and you’ll see something that looks like peaceful abundance, dozens of flower species blooming side by side, bees, butterflies moving between them. But if you look more carefully, it’s not really calm at all—it’s a fierce competition, and it has been going on for hundreds of millions of years. Every one of those flowering plants needs a pollinator in order to reproduce. Meanwhile each pollinator has a limited window of time, energy, and attention. So the real question becomes who gets visited, who gets left aside, and that little difference ends up shaping the evolutionary path of every species in that meadow.

Across the globe, roughly 87.5% of flowering plants are pollinated by animals, which makes pollination one of the most critical ecological dependencies on Earth. And it’s not just a figure for textbooks. About three-fourths of the world’s flowering plants and around 35% of the world’s food crops rely on animal pollinators to reproduce, which means one out of every three bites of food humans eat is tied to this process. The annual economic weight of these pollination services reaches into the hundreds of billions of dollars worldwide, even though most people never think about it.

When plants flower at about the same time, in the same spot, they do not just sit there passively and wait for some pollinator to show up. They compete, a bit, through color, scent, form, and reward—like almost everything about the display. Their goal is to snag the particular visitors that will most effectively move their pollen to a partner flower. And it turns out high competition does not only force plants to “yell” louder in a general way. Instead, it pressures them to advertise more specifically, so much so that co-blooming species often end up differentiating their cues really strongly. Over evolutionary time, this can help them partition the nearby pollinator community, like split up who goes where, and why.

This article then walks through the actual specific signals that plants use when the competition is high—how each one works, how rivalry sharpens it, and what the evidence shows about which cues do the most heavy lifting in which settings.

II. The Stakes of Pollinator Competition

2.1 Why Competition Matters

Competition for pollinators comes in two kind of related but separate ways. One is straightforward resource competition: several plant species bring in the same pollinators, and each one limits the minutes and effort that pollinator can devote to any other species. So a bee that has already stuffed its pollen baskets at a dandelion is basically less available for an orchid growing five meters off to the side.

The second form is arguably more harmful, heterospecific pollen transfer (HPT). For co-flowering species that use the same pollinators, this interspecific pollen transfer kind of battle can steer floral evolution in a big way, because it knocks down female performance through heterospecific pollen landing on stigmas, and it can also hit male success by causing pollen to be misplaced during visits to another species' flowers. When a bee tours two plant species close together in time it ends up carrying pollen from both, on its body. This mixed payload makes it so both plants may receive irrelevant pollen on their stigmas— pollen that clogs normal reproductive routes and blocks successful fertilization.

Co-flowering species are therefore often expected to show divergent floral traits, as a strategy for keeping interspecific competition low. A study based on a three-year field work in a subalpine meadow in southwest China, with 18 floral traits recorded across 44 co-flowering species, showed that trait dissimilarity indirectly lowers heterospecific pollen transfer, mainly by shrinking pollinator sharing. The more unlike two co-flowering plants look, and also the more different they smell, the less likely they are to draw the same pollinators in sequence, and the less likely it becomes that their pollen will end up in the wrong reproductive passage.

This is the evolutionary logic that drives signal differentiation. When competition is high, plants that diversify their signals away from their competitors gain a fitness advantage. Enough generations of this selection can produce the extraordinary diversity of flower forms, colors, and scents we observe in species-rich plant communities today.

2.2 The Pressure Intensifies in Dense Communities

Competition doesn't quite feel equally pressing across every ecological context. Like, a plant flowering by itself in some open field has not much of a real reason to signal with razor sharp specificity. But the moment it flowers at the same time as fifty other species in an alpine meadow, the whole situation flips. The signals matter more, the specificity matters more, and honestly the price of getting it wrong—meaning failing to draw in the right pollinator—can be pretty high.

Pollinator competition can end up shaping how floral resources get partitioned, and it may also nudge the evolution of floral divergence as well as floral syndromes. In fact, sympatric plant species often evolve greater floral divergence than allopatric populations in the same species pair. This overall process, sometimes called reproductive character displacement, is one of the most straightforward evolutionary "fingerprints" of pollinator competition, showing up in both the fossil record and the phylogenetic record.

III. Visual Signals: Color, Pattern, and Shape

3.1 The Language of Color

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UV patterning adds another layer of complexity that most human observers just totally miss, like, completely. These UV patterns come from UV reflection and absorption happening in various floral parts. And the key bit is that they're visible to most pollinators, but for humans they basically vanish, even though we're "looking" at the flower. In practice UV patterns can steer pollinators toward a floral reward, for instance the center-outward UV pattern people often call the UV bull's eye.

Take yellow flowers as a pretty clear case. Petal tips can reflect UV, while central zones absorb it, so the bee's route ends up being pretty well signposted. This works as a guidance signal for where the resources are and where to land, especially for bees. Yellow bee-pollinated flowers frequently show UV color patterns, whereas yellow bird-pollinated flowers don't really show those patterns. And that absence of visual guidance

can discourage bee visitation, because the incentives are harder to “read.” It’s kind of wild that the same yellow color, which looks basically identical to human perception, can send radically different messages to bee’s vs birds—depending on the UV properties, not the visible ones. Overall it’s a beautifully precise signaling mechanism, and it basically lets plants tune their advertisements to specific audiences without changing the gross look of the petals at all.

3.2 Symmetry as a Competitive Tool

Floral shape kinda carries its own information. Bilaterally symmetric flowers— you know, those with a single axis of symmetry like orchids, snapdragons, and a lot of legumes— give a kind of structural hint that tells a pollinator how to come in, where to land and where the reward sits. And that precision, it has big consequences for how plants compete, almost like a quiet advantage that still matters a lot. When a flower is bilaterally symmetric, it can up the pollination specificity, because the whole process of approach and landing becomes easier to do in the “right” way. It also supports more accurate pollen placement onto the pollinator’s body, not just roughly somewhere nearby. More and more evidence points toward the idea that floral monosymmetry improves that fine pollen positioning across different functional groups of pollinators, pretty convincingly. In environments where competition is intense, precision in pollen placement is a major competitive asset. If a plant’s pollen ends up on a bee’s thorax versus its leg, the pollination outcome can flip a lot, depending on where the stigma of the target flower is actually located. Bilateral symmetry in flowers looks like an evolved engineering fix for this whole placement problem, and it has repeatedly pushed diversification in angiosperm lineages. The reason is that it can quickly generate reproductive isolation, especially when slightly different morphologies start aiming at different parts of the pollinator’s body.

As illustrated in Figure 1, the interplay between visual signal divergence and pollinator partitioning in competitive communities follows a consistent pattern across different taxonomic groups and geographic regions.

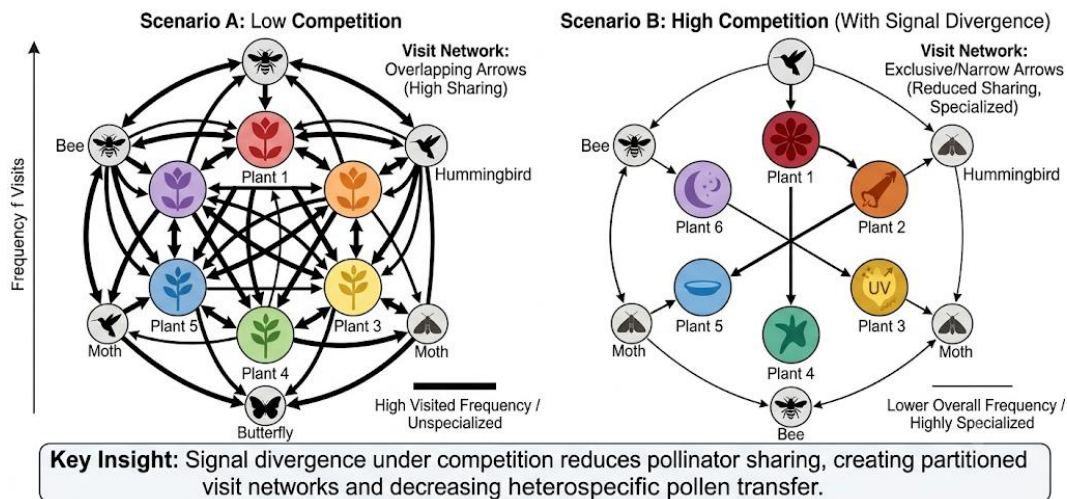


Figure 1: Conceptual Model of Visual Signal Divergence and Pollinator Partitioning in a High-Competition Floral Community

This conceptual diagram sort of shows a community of six co-flowering plant species, as nodes in a circle, and then their main pollinators (bees, hummingbirds, moths, butterflies) appear as separate nodes too. The arrow thickness, means how often visits happen between a pollinator and a plant. In the left panel, the low competition scenario is shown. There the arrows overlap, and you see multiple pollinators visiting multiple plant species, so there is a lot of pollinator sharing going on, it feels kind of tangled. In the right panel, for the high competition scenario, the floral traits diverge more, like distinct colors, UV patterns, and different symmetry types, so the arrows become more narrowed and exclusive, which suggests less pollinator sharing, and a more specialized visit network overall. The main take away, is that signal divergence under competition reduces overlap in pollinator use, which then decreases heterospecific pollen transfer. This model is assembled from empirical results in Temeles & Kress (2003, Science) about Heliconia–hummingbird competition and also Zhang et al. (2025, Oecologia) on floral trait dissimilarity and heterospecific pollen transfer in subalpine meadow communities.

IV. Scent Signals: The Chemistry of Attraction

4.1 Why Scent Encodes Specificity Better Than Color

Color is kind of a broad broadcaster. Even with UV patterns and symmetry layered in there, relatively few distinct color categories actually show up, and a lot of pollinators can still perceive ranges that overlap, more or less. Scent is different though. A flower's chemical bouquet can hold dozens, to hundreds of different volatile organic compounds (VOCs), and the possible combinations across that chemical space are basically infinite.

When you think about signals, color is rarely very pinpoint specific, because most animals have limited abilities to distinguish tiny color nuances. Floral scent, meanwhile, tends to be more important for encoding highly specific signals, largely because its chemical complexity is higher, and there are lots more olfactory neurons involved.

Studies on floral scent composition across plant communities have shown a steady kind of pattern. The dominant VOC classes shift in a predictable way depending on pollinator type. In particular, the monoterpenes trans- β -ocimene and linalool, plus the benzenoid benzaldehyde were the most abundant floral VOCs, both in ubiquity and in how strongly they predominated within blends. Floral VOC richness, relative composition, and emission rates all mattered in the same way, showing important effects from both dependence on different pollinator groups and climate too. Key compounds, or compounds that come from specific biosynthetic pathways, seem to mediate attraction of the main pollinators.

Some of the most extreme cases of scent specificity appear in mimicry systems, like you know orchids that mimic female insect pheromones. They manage to pull in male insects who are really just in search mode for mates, and their scent bouquets are sort of more finely adjusted to the target insect's smell machinery than the actual pheromones of the female they're copying, in a way that is honestly kind of unreal. This sort of signal specificity doesn't really have a counterpart in the visual domain, at all.

4.2 How Competition Shapes Scent Emission

Competition does not only steer which compounds plants end up making, it also shapes how much they go on to emit. There was an important study looking at community level floral scent changes and it found that species which are less abundant, and bloom in spaces with lots of competition, put extra resources into "generalist" attractant compounds. In other words, less common flowering species—those that might be competing with the usual, dominant species for pollinator attention early in the flowering season—end up releasing much higher proportions of the generalist attractant β -ocimene. That gives, what the authors call, a first community-wide account of how seasonal timing ties in with plant specific flower scent emissions.

So, this outcome points to a competitive strategy that is kind of practical. Imagine a rare plant sitting in a community where common-flowering competitors already rule. That rare plant has a problem it cannot really ignore: it must draw pollinators from a pool that is already mostly taken by others. One tactical response is to ramp up emission of a broadly appealing compound, like widening the net, even if it means giving up some specificity.

However, specificity itself can be a real advantage. The flowers of many outcrossing species release a complex blend of volatile chemicals, and those mixtures are thought to boost pollinator visitation. Plants that emit more complex, and more species-distinct volatile mixes tend to get higher pollinator fidelity, meaning pollinators are more apt to come back again and again to the same species. And high pollinator fidelity matters a lot in competitive communities, because a loyal pollinator is basically one that doesn't "waste" your pollen on the flowers of competitors.

V. Nectar and Reward Signals: The Chemistry of Retention

5.1 Beyond Caloric Value

Nectar is often talked about as if it's only a sugar reward, a sort of bribe that plants offer pollinators for the work they do. It's a reasonable idea, but kind of incomplete. Nectar, which is the main floral incentive for many pollinators, doesn't just stay the same it changes a lot in makeup and in how concentrated it is. So the assumption that nectar quality = sugar concentration, is a bit too neat, too direct. There are diverse non-sugar bits too, in particular amino acids and secondary metabolites, and they seem to take on different jobs for the nutrition as well as the overall health of pollinators.

Amino acids in nectar are especially important when it comes to competition dynamics. More and more evidence points to amino acid content as a key factor in shaping pollinator preference and fidelity. In other words, a pollinator that learns a particular flower smell and color as being tied to better amino acid nutrition will start showing strong choices for that species. And those preferences may stick around, even if competing flowers look flashier and are easier to notice. In that way nectar quality can, quite effectively, outweigh other cues in terms of how loyal pollinators stay.

The way nectar is composed also shifts in a way that stays pretty predictable when you look at the pollinator type, and it kinda reinforces that the signal is specific. The sugar concentration in nectar from day-flowering species was about 20% higher, and the amino acid concentration was roughly 2–3 times higher than in nectar from night-flowering species. Meanwhile the sucrose-to-hexose ratio was clearly higher for night-flowering species. Pollinators that can pick up these differences, and most of them can, basically get a chemical cue about which “type” of flower they are touching, and this helps flower constancy stay strong even if they aren’t doing any conscious choosing.

In hummingbird-syndrome flowers the nectar usually has a lower sugar concentration, but it also comes in higher volume. Bee-syndrome flowers tend to go the opposite direction: low-volume nectar but more concentrated. These nectar quirks mirror differences in the feeding technique used by each group. The alignment between how nectar is presented and pollinator body shape is so tight that pollinators end up tasting a cue, not only about reward quality, but also about what sort of visitor the plant is geared for. In turn, that cue lowers the chance of cross-pollinator visits, and it also eases competition for pollinators that are already specialized on complementary flower kinds.

5.2 Secondary Metabolites and Honest Signaling

Some plants stick secondary metabolites into their nectar—substances that are mildly toxic, sharp-bitter, or pharmacologically active for the pollinators that take them in. It might sound counterproductive, but in a competitive, scramble-for-attention setting, these compounds seem to do real work.

Secondary metabolites in nectar can put off generalist visitors, meaning insects that will check out pretty much anything nearby—while specialists, those that evolved resistance or positive cues to the same compounds, can handle it or even benefit from it. In other words, the nectar becomes kinda selective. The metabolites can nudge or interact with the pollinators nervous systems, they shape behavior, they also guard the nectar itself from saprophytic microorganisms and from robbers. And in some cases, they actually support pollinator health too.

So, a plant that places mild toxins in its nectar may discourage non-specialists just enough to keep a cleaner, more faithful back-and-forth with the pollinator it really wants, even when pollinator competition is intense, and everyone is kinda jostling.

VI. Character Displacement: When Competition Reshapes the Whole Signal Suite

6.1 The Evolutionary Response to Competition

When competition for pollinators is sustained over many generations, it does more than nudge individual signals around, it can end up reshaping entire sets of floral traits through a kind of character displacement. The basic idea is pretty straightforward, plants with floral signals that really stand out compared to their nearby competitors tend to pull in more exclusive pollinator visits, they get more conspecific pollen moved between flowers, and they ultimately leave more offspring behind. Over time, natural selection then pushes co-occurring species to drift apart in the way they present those cues.

The experimental evidence here is pretty hard to dismiss. Competition increased within-morph dye transfer (that is, assortative mating) much more than it did in non-competitive settings, in an experimental system that used hummingbird sexes as the pollinators and red and yellow inflorescence morphs of *Heliconia caribaea* as the plants. Also, competition plus the way color morphs got partitioned by sexes of the purple-throated caribs, led to selection for floral divergence, which they measured using dye deposition on stigmas.

So what this particular experiment showed, in a tightly controlled outdoor context, is that pollinator competition directly selects for floral signals that diverge more, in real time. It’s not only a historical readout from patterns observed in nature, it’s a measurable fitness effect that can show up within a single season.

As shown in Figure 2, this pattern of competitive divergence in floral traits plays out across multiple signal channels simultaneously, with color, scent, and morphology often diverging in concert.

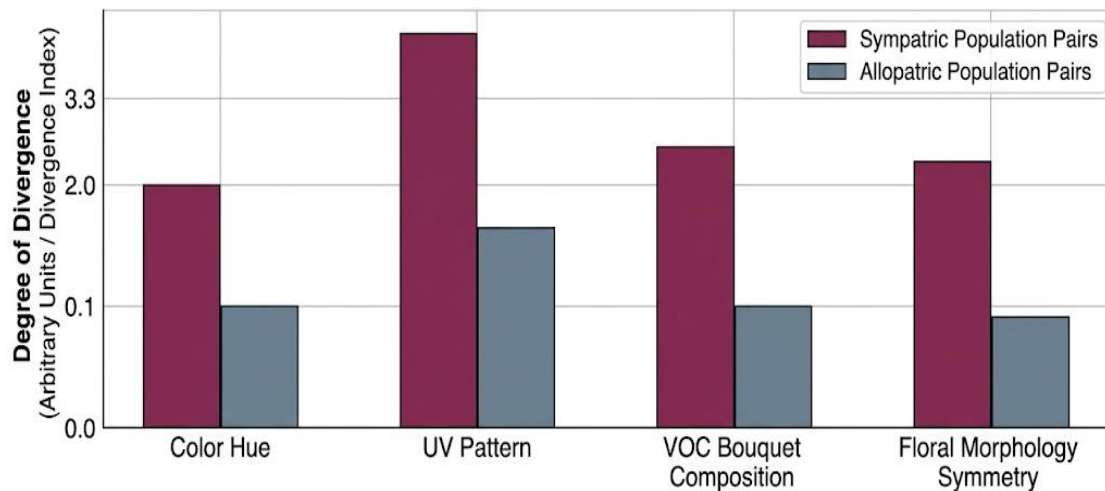


Figure 2: Comparison of Floral Trait Divergence Between Sympatric and Allopatric Plant Species Pairs Across Signal Channels

This bar chart shows how strong the divergence is across four floral signal channels—color hue, UV pattern, VOC bouquet composition, and floral morphology symmetry—between plant populations that live together sympatrically (so, overlapping range with pretty close competitors) and those that live separately allopatrically (different ranges). For each channel, you get a grouped bar layout, and in every case the sympatric bars look consistently taller than the allopatric ones. That pattern suggests more signal divergence when competition pressure is higher, as if the plants are tuning themselves with some kind of careful adjustment. Overall, the figure is put together from synthesized results drawn from Temeles and Kress (2003, *Science*) plus Lambert et al. (2023, *Annual Reviews, Ecology, Evolution and Systematics*) about mechanisms and typical sizes of pollinator-driven character displacement, and also from Zhang et al. (2025, *Oecologia*) focusing on floral trait dissimilarity, along with heterospecific pollen transfer.

6.2 Reproductive Isolation as an Outcome

Pollinator competition that drives character displacement can, in time, lead to reproductive isolation between species that used to be pretty similar. There's a lot of pollination literature showing that reproductive interference often pushes reproductive character displacement, especially in floral traits that matter for pollinator attraction, pollen placement, and the way mating systems get organized, and more recent studies are starting to spell out why interspecific pollen transfer is so important for the whole speciation story.

So the implication is, kind of profound, not just a quick ecological mess for individual plants. It's one of the engines of plant speciation. The astonishing variety in flowering plant bodyplans — about 352,000 angiosperm species (Tong et al., 2023) — likely exists in large part because, over millions of years, plants kept competing for pollinators. Each new round of pressure nudges the floral signals a tiny bit further apart, and eventually there's enough reproductive isolation to generate what we would recognize as new species.

VII. Conclusion

Plants competing for pollinators don't just shout louder. They shout smarter, kind of...like calibrating their colors to the visual systems of the intended visitors, tuning their VOC bouquet profiles to species-specific smell preferences, tweaking nectar chemistry to pay back faithful foragers rather than casual drop-ins, and shaping floral structure so pollen lands in the right spot on the right carrier. When competition is really high, each of these message channels ramps up and gets more specialized, and over evolutionary time the summed outcome becomes the diversification of flower shapes that makes the angiosperm world so visually and chemically remarkable.

The research also suggests, pretty clearly, that no one cue is the boss everywhere. Color tends to work best at distance; scent carries the smallest species-level “this one not that one” signal; morphology handles the pollen placement mechanics; and nectar chemistry ends up deciding loyalty. Put together, these parts make a multimodal signaling system that has been carved—millions of years deep—by competitive pressure into one of the most intricate natural communication setups around.

For conservation and agricultural policy, the takeaway is a bit sharper than it first sounds. Losing pollinator diversity doesn't only mean “fewer pollinators” in the simple sense, it can trigger a potential breakdown of the whole competitive signaling ecology that gives each plant species its particular niche.

Protecting pollinator diversity is , in a very direct way, protecting the evolutionary logic that allows floral diversity to exist in the first place.

References

- [1]. Dellinger, A. S. (2020). Pollination syndromes in the 21st century: Where do we stand and where may we go? *New Phytologist*, 228(4), 1193–1213. <https://doi.org/10.1111/nph.16793>
- [2]. Farré-Armengol, G., Filella, I., Llusà, J., Niinemets, Ü., & Peñuelas, J. (2014). Changes in floral bouquets from compound-specific responses to increasing temperatures. *Global Ecology and Biogeography*, 23(12), 1329–1337. <https://doi.org/10.1111/geb.12205>
- [3]. Food and Agriculture Organization of the United Nations. (2019). *Global action on pollination services for sustainable agriculture*. FAO. <https://www.fao.org/pollination/about/en>
- [4]. Giurfa, M., Núñez, J., Chittka, L., & Menzel, R. (1995). Colour preferences of flower-naive honeybees. *Journal of Comparative Physiology A*, 177(3), 247–259. <https://doi.org/10.1007/BF00192415>
- [5]. Göttlinger, T., & Lohaus, G. (2024). Nectar amino acid profiles and pollination syndromes in red flowers. *Plant Biology*, 26(3), 411–420. <https://doi.org/10.1111/plb.13620>
- [6]. Hawkins, J., De Vere, N., Griffith, A., Ford, C. R., Allainguillaume, J., Hegarty, M. J., Baillie, L., & Adams-Groom, B. (2015). Using DNA metabarcoding to identify the floral composition of honey: A new tool for investigating honey bee foraging preferences. *PLOS ONE*, 10(8), e0134735. <https://doi.org/10.1371/journal.pone.0134735>
- [7]. Lambert, A. M., & Ferreras-Calvo, G. (2024). Importance of pollinator-mediated interspecific pollen transfer for angiosperm evolution. *Annual Review of Ecology, Evolution, and Systematics*, 55, 215–238. <https://doi.org/10.1146/annurev-ecolsys-110218-024804>
- [8]. MacNeill, G. J., Johnson, D., & Sargent, R. D. (2025). Nectar metabolomes contribute to pollination syndromes. *New Phytologist*, 244(2), 498–511. <https://doi.org/10.1111/nph.70217>
- [9]. Nicolson, S. W. (2022). Sweet solutions: Nectar chemistry and quality. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 377(1853), 20210163. <https://doi.org/10.1098/rstb.2021.0163>
- [10]. Oliveira, C., & Brito, V. L. G. (2025). Evolution of UV reflection in bee- and bird-pollinated flowers. *Plant Biology*, 27(3), e70138. <https://doi.org/10.1111/plb.70138>
- [11]. Raguso, R. A. (2008). Wake up and smell the roses: The ecology and evolution of floral scent. *Annual Review of Ecology, Evolution, and Systematics*, 39, 549–569. <https://doi.org/10.1146/annurev.ecolsys.38.091206.095601>
- [12]. Runquist, R. B., Moeller, D. A., & Geber, M. A. (2020). Pollinator divergence and pollination isolation between hybrids with different floral color and morphology in two sympatric *Penstemon* species. *Scientific Reports*, 10, 8081. <https://doi.org/10.1038/s41598-020-64964-8>
- [13]. Schiestl, F. P. (2010). The evolution of floral scent and insect chemical communication. *Ecology Letters*, 13(5), 643–656. <https://doi.org/10.1111/j.1461-0248.2010.01451.x>
- [14]. Schroder, T. S., Gonçalves, F., Vollstädt, M. G. R., Zhang, T., Jensen, R. D., Tarazona-Tubens, F. L., Kim, S., Galetti, M., Simmons, B. I., Kaiser-Bunbury, C. N., Temeles, E. J., & Dalsgaard, B. (2024). Hurricane-induced pollinator shifts in a tightly coadapted plant–hummingbird mutualism. *New Phytologist*, 244, 16–20. <https://doi.org/10.1111/nph.19983>
- [15]. Sponsler, D., Iverson, A., & Steffan-Dewenter, I. (2023). Pollinator competition and the structure of floral resources. *Ecography*, 2023(9), e06651. <https://doi.org/10.1111/ecog.06651>
- [16]. Temeles, E. J., & Kress, W. J. (2003). Adaptation in a plant–hummingbird association. *Science*, 300(5619), 630–633. <https://doi.org/10.1126/science.1080003>
- [17]. Tong, Z. Y., Wu, L. Y., Feng, H. H., Zhang, M., Armbruster, W. S., Renner, S. S., & Huang, S. Q. (2023). New calculations indicate that 90% of flowering plant species are animal-pollinated. *National Science Review*, 10(10), nwad219. <https://doi.org/10.1093/nsr/nwad219>
- [18]. United States Department of Agriculture, National Institute of Food and Agriculture. (2022). *Protecting pollinators critical to food production*. USDA NIFA. <https://www.nifa.usda.gov/about-nifa/blogs/protecting-pollinators-critical-food-production>
- [19]. Vega-Polanco, M., Solís-Montero, L., Rojas, J. C., Cruz-López, L., Alavez-Rosas, D., & Vallejo-Marín, M. (2023). Intraspecific variation of scent and its impact on pollinators' preferences. *AOB PLANTS*, 15(4), plad049. <https://doi.org/10.1093/aobpla/plad049>
- [20]. Zhang, X., Wang, H., Liu, Y., & Ren, Z. (2025). Floral trait dissimilarity indirectly decreases heterospecific pollen transfer through pollinator sharing in a subalpine meadow. *Oecologia*, 207, 55–69. <https://doi.org/10.1007/s00442-025-05694-4>