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Math and pollination: Bees vs. Butterflies

US mathematicians have worked out why the flowers pollinated by bees have sweeter nectar than those visited by butterflies.

When it comes to drinking nectar, the most important factor is whether the insects dip their tongue in, or whether they suck the liquid up.

The sweeter the nectar, the thicker it is, and research found that the dipping method of bees is ideal for drawing up the most viscous liquid.

By making mathematical models that take into account how the thickness, or viscosity, of nectar changes with increasing sugar concentration, the researchers were able to find out what feeding method was best for drinking nectar with varying sweetness, testing the idea that plants and their pollinating insects have co-evolved.

It has been seen in the past that the flowers that bees visit have consistently sweeter nectar than those that butterflies target, but scientists have been unsure of why this is the case.

Thickly sweet

Butterflies and moths drink nectar by actively sucking it through a narrow proboscis, whereas most bees have a tongue which they can dip into shallow nectaries on a flower.

For bees and butterflies alike, there is a constant threat of being eaten while they are feeding at a flower, so they must eat in the most efficient way possible.

While sweeter nectar will contain more calories and energy, it will also be more viscous and difficult to transport.

Butterflies browse large clusters of flowers, probing the blossoms with their proboscises

A nectar-drinker will therefore seek out a flower with an optimal sugar concentration, which can deliver as many calories as possible without being too difficult to extract.

The mathematical models combined with laboratory observations found that the ideal sugar concentration for bees who dip their tongue into nectar was 50-60%, whereas for butterflies it was much less, around 30-40%.

This pattern matches closely with the observed sugar concentration of the flowers visited by bees and butterflies in the wild - around 35% and 20-25% respectively.

While the pattern is the same, the sugar concentration in the wild nectar is considerably less than the optimal concentrations shown by the mathematical models.

Scientists believe this may be because the flowers prefer to keep their pollinators hungry, so that they will faithfully return for more food, pollinating more plants in the process.

Optimizing together

The results are suggestive of the co-evolution of flowers and their pollinators, a pattern that is seen throughout nature.

Prof John Bush from the department of mathematics at Massachusetts Institute of Technology (MIT) in the US, who led the research, explained: "Biological systems are optimized, but to an outside observer it is not always clear what they are optimized for."

"This research has opened up the scope of the optimization problem, as we're looking for the situation that is ideal for the flowers and for the pollinators," he said.

From a plant's point of view, making sure the same kind of creature visits a particular kind of flower makes it more likely that pollen will be transferred between plants of the same species, allowing successful reproduction.

In addition to the sugar concentration of nectar, other features of a flower could be designed to appeal specifically to a certain kind of pollinator.

For example, it is believed that patterns on petals that are only visible in ultraviolet light are designed to attract bees, whose eyes are particularly sensitive to the blue and ultraviolet end of the light spectrum.

Drinking mechanisms in nectar-feeders provide a good natural analogue for more general studies of surface tension in liquids.

"Surface tension is important for things that are small," said Prof Bush. "On scales smaller than a raindrop, surface tension is more important than gravity."

Prof Bush's research group plans to use lessons learnt from these the natural analogues to develop nanotechnology that can deliver fluids on a small scale.

This research into nectar drinking, conducted by engineers and mathematicians, is part of a wider project to categorize, and potentially utilize, the range of drinking techniques in nature.

For example, Prof Bush described the remarkable drinking ability of the Namib Desert beetle. "In the desert it never rains, but this beetle still needs to drink," he explained.

"On its back there are bumps which attract water from the morning mist, and depressions that repel water. When enough water accumulates on the bumps, the droplets are repelled down to the beetle's mouth."

Such a technology has already been developed by MIT researchers into so-called "super plastic", which is used to collect water from the air in the driest regions of the world.

Matt Walker
BBC
Flowers "wave" at insects to get their attention, scientists have discovered.

The finding helps explain why many flowers waft in the breeze, and reveals a hitherto unknown trick used to attract pollinators. Scientists made the discovery while studying common wildflowers known as sea campion on the Welsh coast.

Mobile flowers are visited more often by insects and also produce more seeds, they report in the Journal of Evolutionary Biology.

Moving flowers also attract a wider variety of insect species than more static blooms.

For years, biologists have known that flowers use striking colors, fragrances, elaborately shaped petals and nectar to attract pollinating insects such as bees and flies.

Yet no-one had ever seriously considered whether wafting in the wind acted as a similar signal.

Beachside inspiration

"I was lying on the beach watching flowers wave in the wind at my daughter's birthday party, and I wondered why they have stalks and risked getting damaged in such an exposed habitat," recounted John Warren from the University of Aberystwyth.

So he looked at what research had previously been done, and found very few answers.

"The only reference I found to motion in attracting pollinators says it's unlikely to be important, because insects are not good at detecting movement; which is clearly rubbish."

To find out more, Dr Warren and colleague Penri James experimented with sea campion *(Silene maritima)* growing on an exposed coast within a Site of Special Scientific Interest in Cardigan Bay in west Wales.

They observed 300 specially grown flowers of varying stem lengths, recording how much each flower moved in the wind, how often it was visited by insects and for how long, and how many seeds it went on to produce. Their experiments reveal that flowers mounted on long, thin stalks move around more in the wind.

This acts as a powerful signal to passing pollinators, allowing the plant to attract more insects than less mobile flowers growing atop short, thick stems.

"We found wavy flowers are more visible to insects, and thus attract more pollinators and set more seeds," said John Warren.

But flowers ultimately face an evolutionary trade-off, he believes. "Short, fat-stalked flowers don't wobble enough and are less attractive to pollinators; yet very wobbly flowers are just too wobbly for the insects to handle, as the insects cannot land on them.

"Only flowers that wobble the right amount are successful in setting seeds."