How Bright Is a Butterfly?

The prettiest pollinators match wits with bees

By SUSAN MILIUS

Photos: Dave Cavagnaro/Fenton Communications

Butterflies just don't get respect. Sure, people think they're pretty, but "their attractiveness works against them," grumbles Martha R. Weiss of Georgetown University in Washington, D.C. She's convinced that those rainbow wings join a long list of traits that cause butterflies to be dismissed as too dumb to find their way out of a wet petunia.

To begin with, butterflies aren't social and don't build hives like honeybees. Instead of buzzing purposefully from flower to flower, butterflies flit. Perhaps most important, they don't pollinate major commercial food crops, as bees do. Research has largely followed the money, and butterflies have been marginalized as airheads in a beeist world.

Weiss and several other researchers are working to redress that situation. They have taken a look at butterfly brain power and how it affects pollination, investigating such questions as whether butterflies can learn to associate a certain flower color with a first-rate nectar supply and whether their sipping techniques improve with practice.

Bees may still rank as the smartest pollinators, but butterflies have convinced some researchers that they're more than just a pretty pair of wings. After almost a decade of investigation, Weiss says, "my little crusade is that butterflies are good learners."

Many of the butterfly findings have grown out of studies of bees. "Honeybees are considered to be the intellectuals of the insect world," Weiss says. They're quick on the uptake, reports Randolf Menzel of Free University of Berlin, who has studied honeybees for over 30 years. After just one experience in a laboratory that linked the color violet with a reward, the bees preferred violet to another color, he found. Even the color green, which seemed difficult for them to learn, took just a few rewarding experiences.

Bees have earned the reputation of the smartest pollinators, able to learn odors and the easier colors in just one lesson.

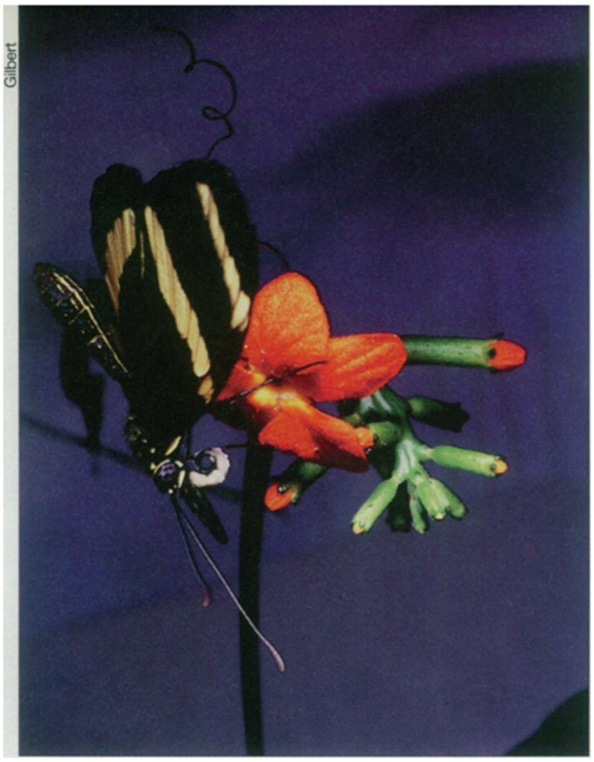
Other experiments have shown that only a single reward session was needed to train bees to choose a particular floral scent about 98 percent of the time. Associating a reward with a putrid odor took longer, but bees achieved the same degree of accuracy.

With such abilities, bees have performed elaborate feats in laboratories. Princeton University's long-time bee researcher James L. Gould has trained bees to choose the lower right petal of a blue artificial flower between 9:30 and 11:00 in the morning and the lower left petal of a yellow flower between 11:00 and 12:30. Their accuracy on these tests reached 80 percent, he reported in the November 1987 ANIMAL BEHAVIOUR. Such capacity comes in handy in the wild because many flowers provide nectar only during certain hours, says Gould.

Butterflies, whose color vision detects more wavelengths than either humans' or bees', can also associate colors with rewards. In one of the more dramatic experiments, cabbage butterflies learned a color with beelike speed—after just one experience with a reward. Given a choice of two colors, the butterflies picked the rewarding hue 82 percent of the time, reported Alcinda C. Lewis of Boulder, Colo., and a colleague in *Insect-Plant Interactions* (CRC Press, Boca Raton, Fla., 1990). Pipevine swallowtails learned a preference for yellow or magenta within 10 visits to treat-laden flowers, reported Weiss in the May 1997 ANIMAL BEHAVIOUR.

The butterflies could also keep two learned colors in mind for different purposes, Weiss says. She and Daniel R. Papaj of the University of Arizona have trained female pipevines to associate one color with sources of nectar and another with suitable spots for laying eggs.

Gilbert



The tropical Heliconius species may be the Einsteins of the butterfly world, with daily foraging paths and nightly roosting spots.

Weiss first became interested in what butterflies could learn when she was studying flowers she believed had evolved as teachers. She proposed that blossoms which change color as they age give pollinators lessons in using color signals to pick out the freshest, nectar-rich flowers.

At least 214 genera of flowers contain species that shift color as they age, Weiss noted in the Nov. 21, 1991 NATURE. She's not talking about a dimming of the blush on an aging rose, but about changes as clear as traffic lights. Flowers on one lantana, for example, spend their first day as yellow then turn orange and, eventually, red. Sometimes just a small part of the blossom signals aging. In one lupine, a white spot on a petal turns purple, and in some forget-me-nots, the central yellow corona becomes white. In the 26 species she's checked, the color change marks the end of nectar availability.

Even though the older flowers on these plants no longer need to attract pollinators, Weiss speculates that they add mass and dazzle to a plant's display to help lure visitors. "Instead of just looking like a little scrawny green bush, [it looks] more flowery," she explains. When she offered butterflies various sizes of blossom clumps, bigger was better—even if the larger clumps held no extra nectar.

By observing butterflies on the clumps of color-changing lantanas, Weiss found that buckeyes and gulf fritillaries learn to avoid frumpy old blooms. The first time the butterflies encountered a clump, they probed for nectar in both the rich yellow blossoms and the red duds. After several days, the butterflies concentrated on yellow flowers.

Once a butterfly has learned a color, it can switch to another one, Weiss points out. When she changed the reward scheme in the color-choice test for her pipevine swallowtails, they changed preferences within 10 visits to the flowers.

That's better than small skippers did in a test devised by Dave Goulson and J.S. Cory of the University of Southampton in England. Three days after a switch in reward systems, 46 percent of their butterflies were still looking for nectar in the wrong places, they report in the November 1993 ECOLOGICAL ENTOMOLOGY. They chalked the slowness up to butterfly dimness, but Weiss wonders if it's a matter of how long the butterflies trained on the first system—3 days in Goulson and Cory's experiment but only 1 in hers. Even bees have trouble switching if they train too long on one reward situation.

Finding the right flower is only the beginning of a pollinator's challenge. The insect must then locate and tap the nectar chamber, a task that bees seem to learn to do faster as they buzz through life. When confronting a jewelweed's sculpted windsock of a flower, about half of the inexperienced worker bumblebees landed in the wrong place and probed the wrong spot, says Bernd Heinrich of the University of Vermont in *The Biology of Learning* (Springer Verlag, Berlin, 1984). Those fumbling recruits visited one to three flowers a minute, while an experienced colleague zipped through 11 in that time. After the first 100 or so blossoms, bees get adept at even the most baffling blossom shapes.

Butterflies also seem to refine their nectar-gathering technique, says Lewis, who pioneered butterfly pollination studies. A cabbage butterfly's first visit to a bellflower or trefoil involves some 10 seconds of groping before finding the right place to sip. By the third or fourth blossom, however, the butterflies are drinking in less than half the time.

Some flowers seem Sesame Street easy, while others demand rocket science, Lewis reports. She clocked butterflies on blooms of 11 species, ranging from the slim cup of an oxalis, which butterflies figured out quickly, to the winged tube of a clover, which butterflies struggled with for almost 20 seconds on the first try.

Shape does not always explain differences in learning times, she says. Butterflies took longer learning how to drink from tufted vetch than from crown vetch, both on the first try and on later approaches. The flowers looked equivalent to Lewis, so she speculates that some kind of scent or marking gives a butterfly a special tutorial in the second flower.

Butterfly researchers have echoed yet another aspect of bee research: investigating whether learning to handle a second type of flower destroys an insect's facility with the first. For bees, the evidence suggests at least some costs of switching species. Bumblebees that work a patch of mixed flowers suffer from shuttling among dissimilar flower shapes, reports pollination researcher Terence M. Laverty of the University of Western Ontario. The bees took more time and made more mistakes than bees that stuck with the same species.

Lewis found a similar interference effect in cabbage butterflies. Insects that had once sipped bellflower nectar like pros fumbled like first-timers after they had been forced to partake of trefoils for a while.

Darwin proposed that such interference explains why pollinators tend to visit a

Like other pollinators, butterflies tend to visit a string of flowers of the same species, ignoring other blooms, though researchers are not sure why.

string of flowers of the same species while ignoring other, perfectly good blossoms.

From the plant's point of view, such pollinator constancy is vital for successful cross-fertilization. Unless a pollen-dusted bee buzzes away to another flower in the same species, the plant's energy is wasted.

From the insect's point of the view, however, flower constancy seems daft. Why not just fly to the nearest flower offering lunch?

"[N]o one will suppose that insects act in this manner for the good of the plant," Darwin wrote in 1895. "The cause probably lies in insects being thus enabled to work quicker; they have just learned how to stand in the best position on the flower, and how far and in what direction to insert their proboscides."

As Goulson puts it, "You stick with what you're good at."

According to Darwin's theory, the insect's limited learning ability plays a role in the evolution of flower shapes. A plant that's a little tricky to learn—not too hard but not too easy—may reap the reward of greater constancy if pollinators who master the technique tend to keep using it.

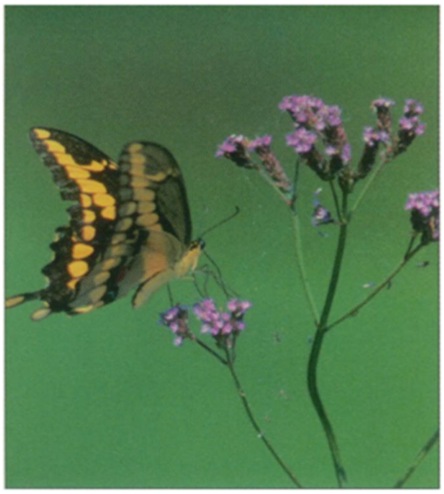
Although this notion has loomed large in pollination biology, scientists have only recently begun to test it rigorously. In fact, research that measures the time saved by fidelity raised questions about whether it offsets the inconvenience of searching for a particular species.

Again, bee researchers have taken the lead. Laverty has observed that bees in the wild dallying among four species with flowers of simple shapes don't seem to suffer any interference effects. Only when switching from one tricky flower to another do they show the predicted interference costs. Even then, the interference seems minimal—only an extra second or so.

Small skipper butterflies also show slight effects, report Goulson and his colleagues in the Oct. 1 1997 OECOLOGIA. They watched the butterflies under natural conditions and found that flower-handling time increased by less than 1 second after a species switch. He hesitates to say whether that's too little to matter to butterflies.

Much of the pollination-related work has focused on species that live in the temperate zone. However, "if you're looking for the Einstein of butterflies, it ought to be *Heliconius*," Goulson says. A long-time specialist in this tropical genus, Lawrence E. Gilbert of the University of Texas at Austin, agrees that *Heliconius* includes "probably the most intelligent butterflies."

Natural selection may exert more leverage on *Heliconius* brainpower than it does on other species because the adult butterfly emerges in need of some 80 percent of the food resources required for laying its eggs. Other tropical butterflies



A butterfly that gets the hang of extracting nectar from one kind of flower may lose its facility when it learns to handle a second type.

spend more than three times as long in immature stages, bulking up on leaves and storing resources for eggs. Smart adult foraging wouldn't make as much difference in their reproduction. "They just have sex and sip a little nectar and have the trivial lifestyle that gives butterfly biologists a bad name," Gilbert says.

As well as sipping nectar, *Heliconius* species eat pollen, the only butterflies known to do so. They generally live 4 to 6 months, and they forage along the same route every day, as if following a trapline from one favored plant to the next. "If you cut down one [plant], they still visit the site for several days," Gilbert says.

He's convinced that they learn these routes, as well as the locations of the saplings or branches where they roost each night in groups of 5 to 20. These butterflies will even avoid for several days any spot where an entomologist has swooped them into a net and released them.

Just how their spatial systems work is not clear, says Evandro Oliveira of the University of Texas at Austin in as-yet-unpublished research. His tests in a greenhouse failed to demonstrate spatial learning, at least on a small scale.

Oliveira has no doubt that *Heliconius* butterflies can learn, because he has repeated and refined some earlier studies of their skills in associating flower color with a reward of sugar water. "They learn colors as fast as bees," he says.

As Gilbert muses on the prowess of *Heliconius*, he points out that people assign great value to their own kind of intelligence—essentially, flexibility in behavior. Butterflies that develop a foraging route get lots of acclaim for being smart, even though other butterfly species do phenomenal things with different systems.

"Look at the monarchs," Gilbert says. They migrate thousands of miles and pinpoint locations no one in their generation or possibly their parents' generation has ever seen. "That's not learned," he says, "but it's biologically smart." □