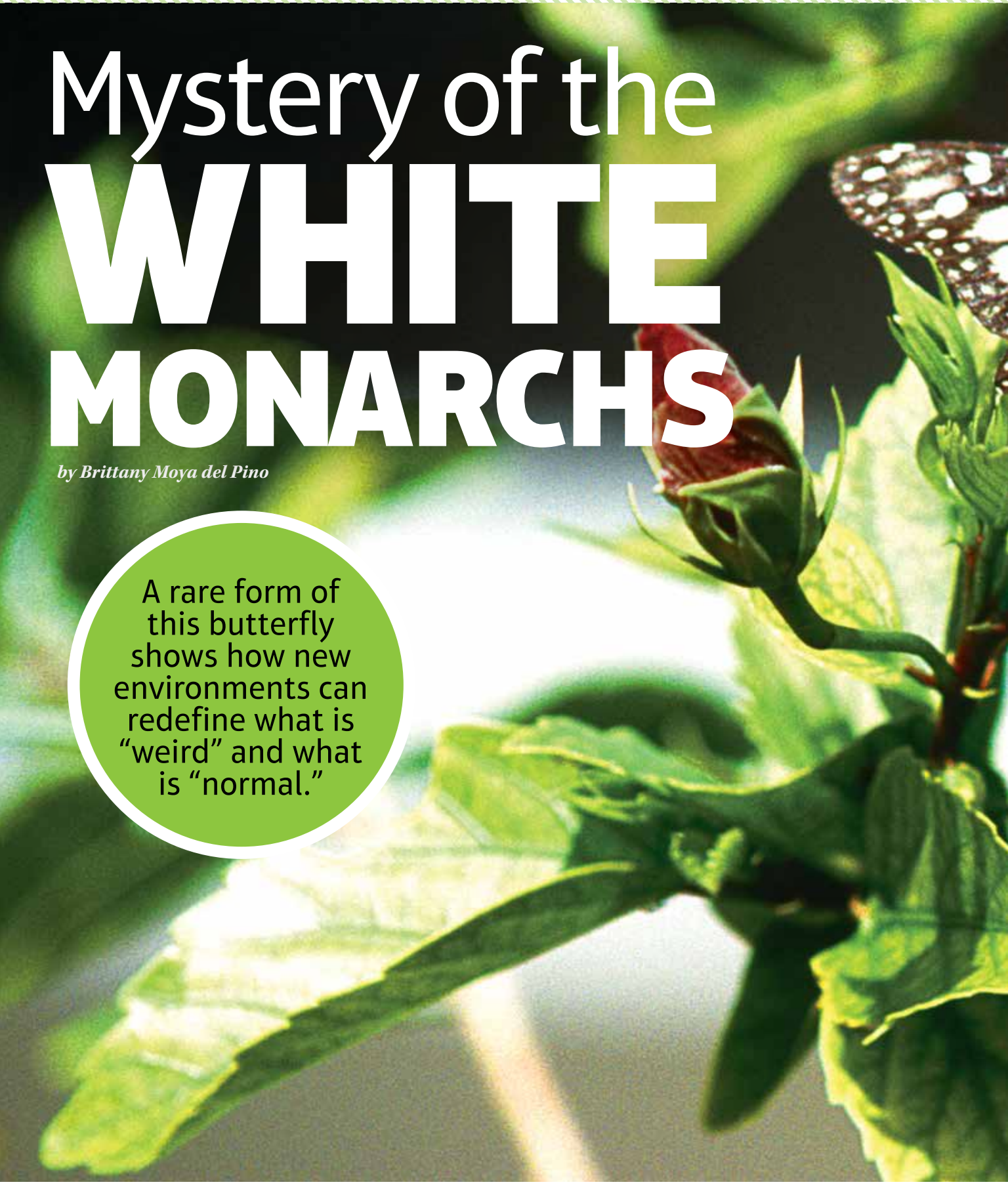
Mystery of the WHITE MONARCHS

by Brittany Moya del Pino

A rare form of this butterfly shows how new environments can redefine what is "weird" and what is "normal."



It was his first day of class on the University of Hawaii campus, and Mark Berman, a 27-year-old biologist-in-training, was stoked to learn about bugs in the tropical island ecosystem of Oahu. He strolled across campus in search of the zoology building when something familiar caught his attention: an enormous bush, almost like a multi-trunk tree, with clusters of purple flowers and large, pale-green leaves whirring with insect activity. It was a giant crown flower plant, part of the milkweed family. Caterpillars striped black, yellow, and white, as long and thick as Berman's finger, were going to town on those fuzzy leaves, stripping the juicy crop bite-by-bite while orange and black butterflies darted among the branches, searching for mates.

Berman recognized the caterpillars and orange and black butterflies right away. They were monarchs, *Danaus plexippus*. He saw hundreds of their empty papery chrysalises overhead, still anchored to the bottom of a second-floor balcony. Berman's gaze lowered to the windows on the first floor, to a research poster published by a professor named John Stimson. And that's when he spotted the photograph of a very special, rare creature, which he'd never seen before: the white monarch butterfly, also known as the *nivosus* morph.

Snacking on monarch butterflies will usually make a bird toss its cookies. This blue jay will steer clear of the distinctive-looking insects from now on.

ORANGE AND BLACK ARE SO TYPICAL

Monarch butterflies come in two color combinations: orange and black, or white and black. Not many people know about the white version, and even fewer have ever seen it. It's an outlier, an oddball, and a prime target for predators. The butterfly's typical orange and black wing pattern serves as a warning flag to advertise its toxicity, which the monarch borrows from chemicals in the milkweed leaves that it eats. (Biologists call this warning coloration an "aposematism.") All it takes is one nasty taste, and a blue jay will barf up its mouthful of monarch butterfly and never attempt to eat one again. White monarchs taste just as terrible as orange ones, but they're so rare that even if a bird eats a white monarch and learns to avoid others that look like it, there aren't enough white ones left to benefit from the bird's lesson.

Nivosus shows up now and then in seemingly random places and then it just disappears. But on the island of Oahu, right around the mid-1960s, white monarchs started to show up more frequently. They stuck around and multiplied. By the time Berman arrived on campus, in the 1980s, their numbers had grown to more than 8 percent of the overall monarch butterfly population. Something about the island had given these oddballs a new edge.

RISE OF THE FREAKS

Every species has its quirks. Tigers in India are sometimes born with black stripes on a white coat. Black bears in Canada might enter the world wearing white fur, despite their name. Ladybugs may have orange spots on a black background, rather than the inverse. These differences are called "polymorphisms," and

human populations have them too.

For example, scientists believe that all humans had brown eyes until about 10,000 years ago, when blue-eyed freaks showed up near the coast of the Black Sea. These weirdos with blue eyes migrated north and west into Europe, increasing their numbers among the brown-eyed population. Blond hair is another rare variation found in Europeans, and also in the Solomon Islands. Between 5 and 10 percent of people from the Solomon Islands have blond hair and dark skin. But what makes a Solomon Islander's hair blond is totally different from what makes blond hair in Europeans.

Polymorphisms come from genes, portions of DNA that carry instructions to make the building blocks of living bodies. Both humans and butterflies get two copies of every gene, one from mom and one from dad. These copies can represent different versions of a gene, and one version might be stronger than the other. When this happens, the stronger copy is called a "dominant allele" that overcomes, or hides, the visible features of the weaker copy, which is called a "recessive allele." White wings are a recessive allele in monarch butterflies. If monarch parents are orange, both of them must have at least one copy of the recessive allele in their DNA. Then, they must both pass that allele down for their butterfly offspring to appear white.

Zoologist John Stimson, a professor at the University of Hawaii who specializes in corals reefs, noticed the white monarch butterfly boom on campus. He was intrigued. He knew that Hawaiians had sent a white specimen to a London museum in 1890, and that reports from Hawaii during the early 1900s showed that whites were extremely rare. So what was it about the 1960s that had caused white monarchs to become more than a blip on the butterfly population radar? Stimson had taken this on as a side project. When Berman arrived on campus, he offered to help.

After a couple years of watching the monarchs in four locations across Oahu, they learned that monarch butterflies make a tasty snack for bulbul birds. These birds don't seem to mind the milkweed toxins stored in the monarch's flesh. Bulbuls gulp them like candy, snagging adult butterflies mid-air with a quick clip of the insects' wings before tearing open their abdomens to get the juicy stuff inside. Judging from the carnage they leave behind—disembodied butterfly wings, mostly orange, scattered like autumn leaves on the ground—bulbuls are most likely to target orange monarchs. The percentage of live white butterflies that Stimson and Berman caught in their nets also indicated that bulbuls prefer to attack orange monarchs, maybe because their color especially stands out from certain leaves and flowers. Stimson and Berman published these results in the journal *Heredity* in 1990.

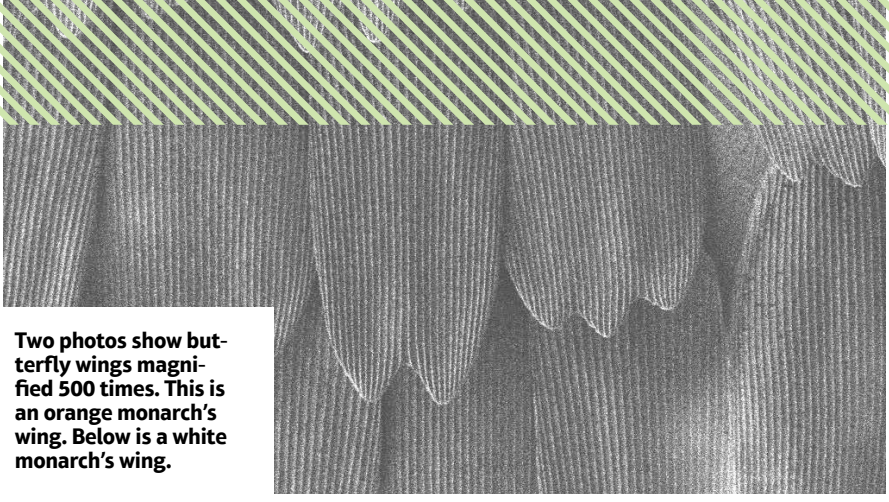
That same year, Berman finished his undergraduate degree and was ready to move on to graduate school on the mainland United States, where he switched to studying science

Bulbul birds in Hawaii were willing to eat orange monarchs. Brave bulbuls.

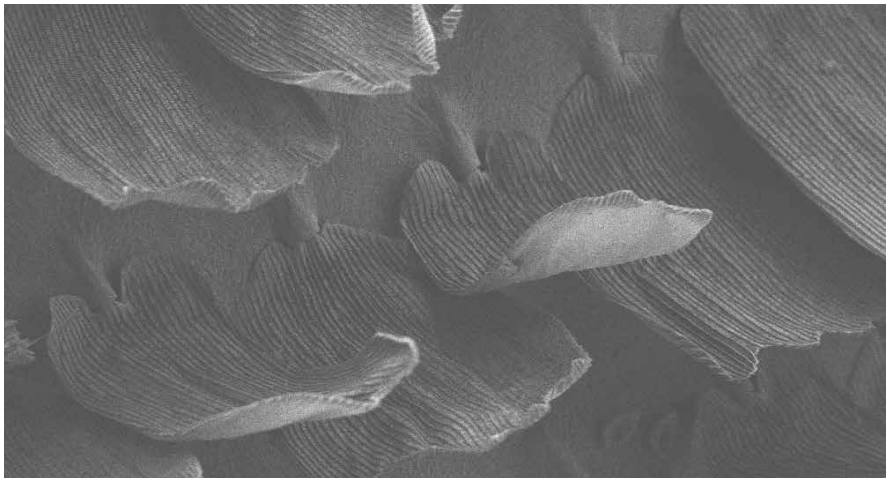
education and then mosquito ecology. Professor Stimson continued to track the progress of the white monarchs on Oahu. By the year 2000, when he published a follow-up article in the *Journal of the Lepidopterists' Society*, the frequency of white monarchs had fallen back to 1.7 percent.

A CLOSER LOOK

Meanwhile, a Hawaiian woman named Dancetta Feary had taken on monarch butterflies as her pet project. She was raising and selectively breeding for white monarchs and doing quite well at it: at one point she had hundreds of them living in cages in her backyard on Oahu. When Marcus Kronforst wanted to study the genetics of monarch butterfly migration and coloration, he contacted her to ask for a few dead ones from Hawaii. Kronforst is an evolutionary biologist who



Two photos show butterfly wings magnified 500 times. This is an orange monarch's wing. Below is a white monarch's wing.



studies butterflies at the University of Chicago. His team sequenced the genomes of over 100 monarch butterflies, including the Hawaiian white monarch. This research revealed features in a single gene—DPOGS206617—that all of the white butterflies shared.

No one knows yet what this gene actually does. Might it produce a pigment protein, or something else? Kronforst looked for clues in the genome maps of other insects. He came to realize that DPOGS206617 might produce a protein that supports the overall structure of cells. Pigments partially control butterfly wing coloration, but it's also controlled by prism-like structures that can bend and spread white light. It was time for Kronforst to take a closer look at the actual wings with an electron microscope to get a better sense of what is going on.

DOES WEIRD = WRONG?

"As soon as I put them under the microscope, I could see something different," he explains. A butterfly's wings are normally covered in flat, overlapping scales, and Kronforst saw that in the white portions of the *nivosus* wing, the scales are actually pale gray.

"When you look at those gray scales, they are absolutely kooky," Kronforst says. "They're misshapen, wrinkled, and they fit together tangentially." However, in the black portions of the white monarch wings, the scales look totally normal. This means that DPOGS206617 has its effect—whatever that might be—only in light-colored patches of the wing.

Wrinkly wing scales bring up the question: are white monarchs defective? Feary thinks they might be. All the white ones she had raised on Oahu have now died; their babies didn't survive long enough to mate for a new generation. But at the University of Kansas, monarch scientist Orley Taylor has been raising healthy white monarchs in his lab, and he hasn't seen any signs of weakness. "They're highly inbred," Taylor says, "but they're still very fit."

UNSTOPPABLE MUTANTS

Today, white monarch butterflies in Hawaii have returned to rare status, just as they are nearly everywhere else. The forces that once helped them multiply on Oahu—bulbul birds that leveled the survival playing field—are no longer working to the whites' advantage, and nobody knows for certain why, though Stimson suspects that a switch from eating adult butterflies to eating caterpillars may be a cause. There have been no reports of white monarchs on the neighbor islands surrounding Oahu. Meanwhile, even some scientists who have spent their whole careers studying monarch butterfly migration in North America have never, not even once, seen a white monarch butterfly in the wild.

Many questions about the white monarch butterflies remain unanswered. How exactly does the mutant gene produce white wing coloration? And if the nivosus gene is simply recessive, then why does a white one suddenly appear out of the blue after a small, captive population of orange monarchs has produced nothing but orange offspring for many generations? Can the recessive gene that causes white wings mutate spontaneously, without any history of that gene in the parents?

Berman owns a company in Ohio now called Bugman Education. He frequently visits schools and other public events to teach kids about insect biology and ecology, but he doesn't always take monarch butterflies along. "They're sort of high maintenance," he says. "They eat *a lot* of leaves, and they poop a lot." He prefers to take tarantulas and other long-lived arthropods on his school visits. Monarchs are a seasonal favorite, though, along with other local bugs.

He has seen three recent reports on Facebook from backyard breeders of monarch butterflies who found a white one in their stocks. One woman from Virginia sent him a picture, and he's pretty sure it was the real deal. Other whites have been reported in Missouri, Pennsylvania, California, Florida, Washington, DC, and even as far as Indonesia. These are isolated cases: single white monarch butterflies in a sea of orange brothers and sisters.

However, in 2001, a year after Professor Stimson reported the Hawaiian population of white monarch butterflies had shrunk to 1.7 percent, another report surfaced from researchers in Australia. White monarch butterflies had established a stable colony on the island of Aneityum, which is part of the archipelago nation Vanuatu, just northeast of Australia. Their numbers had grown to nearly 20 percent of the local monarch butterfly population—the highest reported frequency of white monarchs *ever*.

Could these Vanuatu white monarchs be genetically similar to the white monarchs from Hawaii? If so, did the ancestors of these butterflies migrate thousands of miles across the Pacific Ocean to establish their colony with the same mutated gene? Or is the Vanuatu *nivosus* situation similar to blond hair in the Solomon Islands? The Australian researchers described Vanuatu's butterflies as pinkish-white, rather than grayish-white, so maybe a different gene is at work there. Researchers haven't sequenced the genomes of any butterflies from Vanuatu yet, but they're going back to Aneityum soon to check for new specimens, and other scientists are sequencing more monarch genomes, so eventually we may have some answers.

READY AND WAITING

What we know for now is that when the surrounding environment puts pressure in favor of or against a particular version of a gene, then one version becomes common and the other may get squeezed out of the population, sometimes to the point that it seems to have disappeared. But as long as the squeezed gene isn't inherently deadly, it can linger in the genetic pool almost like an evolutionary life raft, in case the environmental rules happen to change.

This is what happened to the peppered moth in England during the nineteenth century. For as long as anyone could remember, peppered moths had been white with light gray spots, except when a weird dark one would show up—and quickly get eaten because it was visible against light tree bark. During the rise of industrialization in Europe, however, as a layer of soot settled over the British landscape, white moths resting on a grimy tree trunk were the first to get eaten and dark moths simply blended in. Dark moths lived long enough to reproduce, and the overall appearance of the population began to shift so that what was once weird became the new normal. That is, until clean air laws helped to decrease pollution. Then the peppered moth population shifted again. This time, conditions favored the white wings.

Brittany Moya del Pino lives on the island of Oahu in Hawaii, where she admires local butterflies but abhors the local cockroaches. Her story about daydreams appeared in the September 2014 issue of *Muse*, and her story about whispering spots appeared in our February 2015 issue.