It’s a summer scene so common that we humans seldom stop to notice. A butterfly gingerly alights on a bush or a flower and unfolds its magnificent wings, revealing iridescent bands of blue.

For the Red-spotted Purple, one of New England’s prettiest butterflies, the display is a warning to hungry predators. Interested birds can see all they need to see to leave the butterfly alone.

In this case, however, predators are being duped; the Red-spotted Purple—Limenitis arthemis—is a gorgeous fake, a mimic that has co-opted the appearance of its toxic cousin, the Pipevine Swallowtail. How did such mimicry come about? How did one butterfly species so effectively usurp the warning signal of another?

Sean Mullen, a College of Arts & Sciences assistant professor of biology, is trying to find out. He and Harvard University evolutionary biologist Marcus Kronforst were awarded a $980,000 grant from the National Science Foundation in November 2010 to identify the specific genetic mutations responsible for mimetic wing pattern variation in three species of butterfly: Admirals (Limenitis), Swallowtails (Papilio), and Longwings (Heliconius).

There are approximately 18,000 species of butterflies on the planet, and Mullen says their wings are “some of the most diverse morphological appendages in the natural world.” Beyond their extraordinary beauty, wings play an important role in courtship,
Beyond beauty

Butterfly wings are among the most diverse appendages in nature. They play important roles in courtship, thermoregulation, predator avoidance, and locomotion.

This functional complexity belies a relatively simple two-dimensional structure. Butterfly wings are essentially a sheet of scales just one cell thick. Add this architectural simplicity to the fact that butterflies are easy to breed in a lab, he says, and they are a "phenomenal genetic model."

Sometime in the last 200,000 years, the Red-spotted Purple lost its stripes, literally, a result of a genetic fluke. A butterfly emerged from its cocoon intact, but unlike the others in its Admiral family, lacking the prominent white band through the middle of its wings.

Mullen points out that a wing pattern mutation such as this would typically cause a butterfly to stand out to its enemies. But this mutation offered an unforeseen advantage: the new, stripeless butterfly looked a lot like the Pipevine Swallowtail, whose poisonous effects were well known to predators.

"If you’re a bird, you learn quickly to avoid anything that’s big, black, with blue on the hind wings," he says. The accidental mimic was thus blessed with a much greater chance of survival than its apparently nontoxic siblings, and consequently, with a greater chance that the fluke would become the norm.

Mullen and his team are making strides in their efforts to locate the mutation. They now know which chromosome (out of a possible 30) contains the gene that controls wing pattern. More specifically, they’ve identified which portion of that chromosome holds the answer.

“We have mapped one interval in the genome that we know the gene is in there somewhere,” he says. "It’s cool. It’s very cool."

From here, Mullen will zero in even further. Using 1,000 butterfly genomes—many of the specially bred insects reside in his lab’s freezer—he will embark on a series of steps that combine genetic fine-mapping and next-generation DNA sequencing technology. Through this process, which, put simply, comes down to matching patterns, he will ultimately figure out which gene caused the butterfly’s appearance to change thousands of years ago.

Down the road, Mullen hopes we will learn whether the wing patterns of all butterfly species are controlled by the same set of genes or by varying ones. In other words, does a common genetic architecture regulate the development of wing pattern or is it decided by several different architectures? The answer will help inform how scientists view the process of natural selection.

“Both outcomes would be really quite interesting,” Mullen says. One result would indicate predictability in evolution, he says, while the other would suggest flexibility.

If it turns out that all butterflies use the same set of core genes to establish wing pattern, that would imply a certain predictability in evolution. “You might expect, at the genetic level, that certain changes are going to produce certain shifts in appearance,” he says. “Predictable would be fantastic.”

If, on the other hand, very different genes control wing pattern, that would suggest evolutionary flexibility—that different genetic pathways can ultimately lead to the same changes in attributes.

“That would be exciting too,” says Mullen, “because it would suggest that the genomes of organisms are flexible enough that there are multiple solutions to common problems.”

Such knowledge will also have implications for larger issues, like genetic disease. “It’s important from our perspective as humans,” he says. “We’d like to know when we see a particular disease, is it going to be the same across all human populations?”

Mullen’s driving interest is understanding the history and origin of life and why it’s so varied. Studying the wing patterns of butterflies is one step toward unearthing answers to such larger questions.

“You might actually be able to look at an entire group of organisms and begin to gain an understanding of why they’re so diverse and how they produce such amazing diversity,” he says. “That gets me really excited.”