# What do soap bubbles and butterflies have in common?

April 7 2020, by Robert Sanders

Comparison of wild-type brown buckeye and artificially selected blue buckeye wings. Credit: Aaron Pomerantz

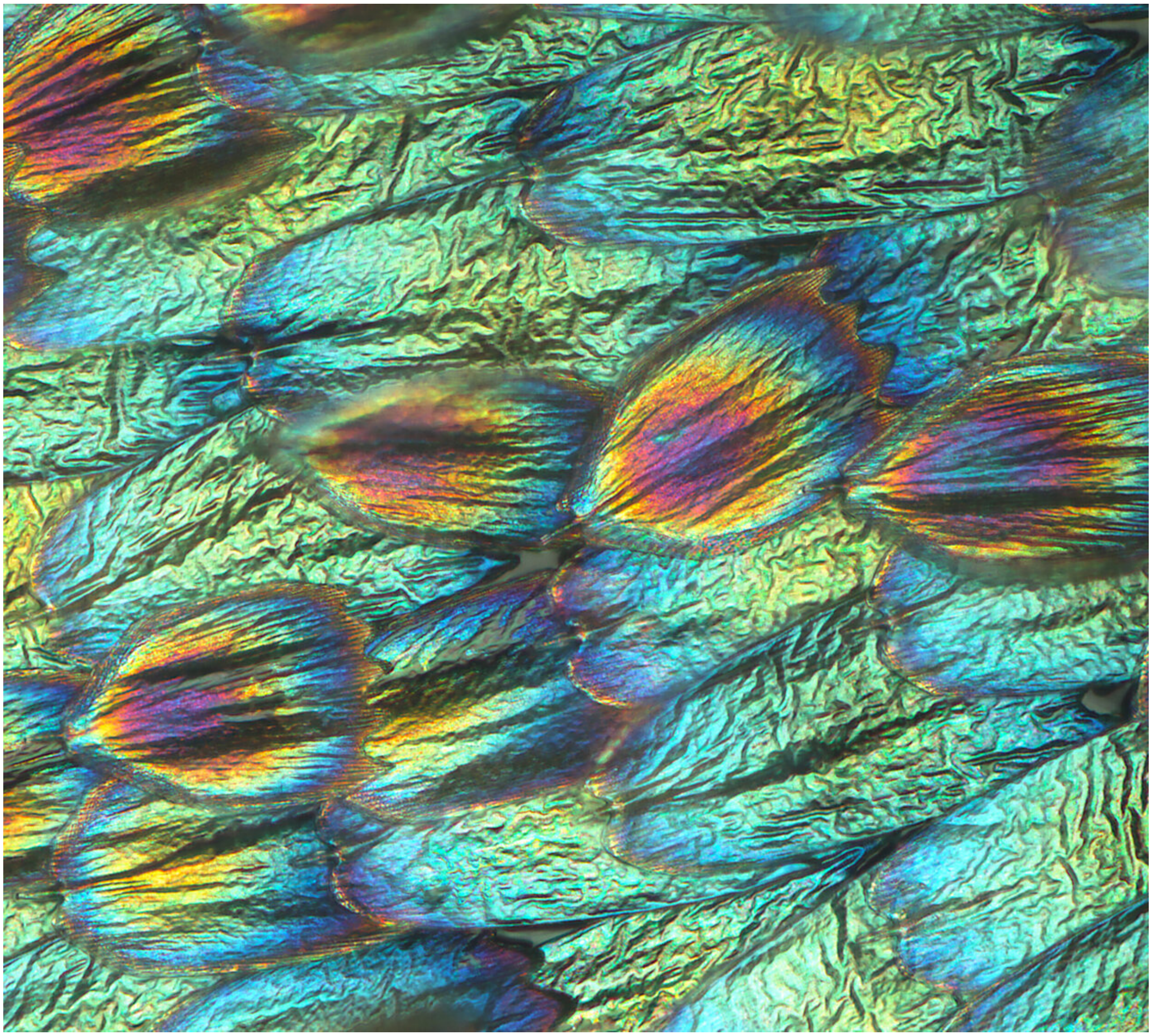
Edith Smith bred a bluer and shinier Common Buckeye at her butterfly farm in Florida, but it took University of California, Berkeley, graduate student Rachel Thayer to explain the physical and genetic changes underlying the butterfly's newly acquired iridescence.

In the process, Thayer discovered how relatively easy it is for butterflies to change their wing colors over just a few generations and found the first gene proven to influence the so-called "structural color" that underlies the iridescent purple, blue, green and golden hues of many butterflies.

Her findings are a starting point for new genetic approaches to investigate how butterflies produce intricate nanostructures with optical properties, which ultimately could help engineers develop new ways to produce photonic nanostructures for solar panels or iridescent colors for paints, clothing and cosmetics.

Structural color is different from pigment color, like that in your skin or on a canvas, which absorbs or reflects different colors of light. Instead, it comes from light's interaction with a solid material in the same way that a transparent bubble develops a colorful sheen. The light penetrates it and bounces back out, interfering with light reflected from the surface in a way that cancels out all but one color.

At the Shady Oak Butterfly Farm in Brooker, Florida, Smith's breeding experiments with the Common Buckeye (Junonia coenia)—a mostly brown butterfly with showy, colorful spots, found throughout the United States and often raised by butterfly farmers for butterfly gardens or wedding ceremonies—were ideal for Thayer's study of structural color.



Underside of artificially selected blue buckeye butterfly wing scales showing their iridiscent lamina colors. Credit: Rachel Thayer

"Edith noticed that sometimes these butterflies have just a few blue scales on the very front part of the forewing and started breeding the blue animals together," said Thayer, who is in UC Berkeley's Department of Integrative Biology. "So, effectively, she was doing an artificial selection experiment, guided by her own curiosity and intuition about what would be interesting."

In a paper appearing online today in the journal *eLife*, Thayer and Nipam Patel, a UC Berkeley professor of molecular and cell biology who is on leave as director of the Marine Biological Laboratory in Woods Hole, Massachusetts, describe the physical changes in wing scales associated with Smith's experiment on the Common Buckeye, and report one genetic regulator of blue iridescence.

"I especially loved the clear evolutionary context: being able to directly compare the 'before' and 'after' and piece together the whole story," Thayer said. "We know that blueness in J. coenia is a recent change, we know explicitly what the force of selection was, we know the time frame of the change. That doesn't happen every day for evolutionary biologists."

## Structural color produces showy butterflies

According to Thayer, hundreds of butterflies have been studied because of the showy structural color in their wing scales. The showiest is the blue morpho, with 5-inch wings of iridescent blue edged with black. Her study, however, focused on a less showy genus, *Junonia*, and found that iridescent color is common throughout the 10 species, even the drab ones. One unremarkable light gray butterfly, the pansy *J. atlites*, proved under a microscope to have iridescent rainbow-colored scales whose colors blend together into gray when viewed with the naked eye.

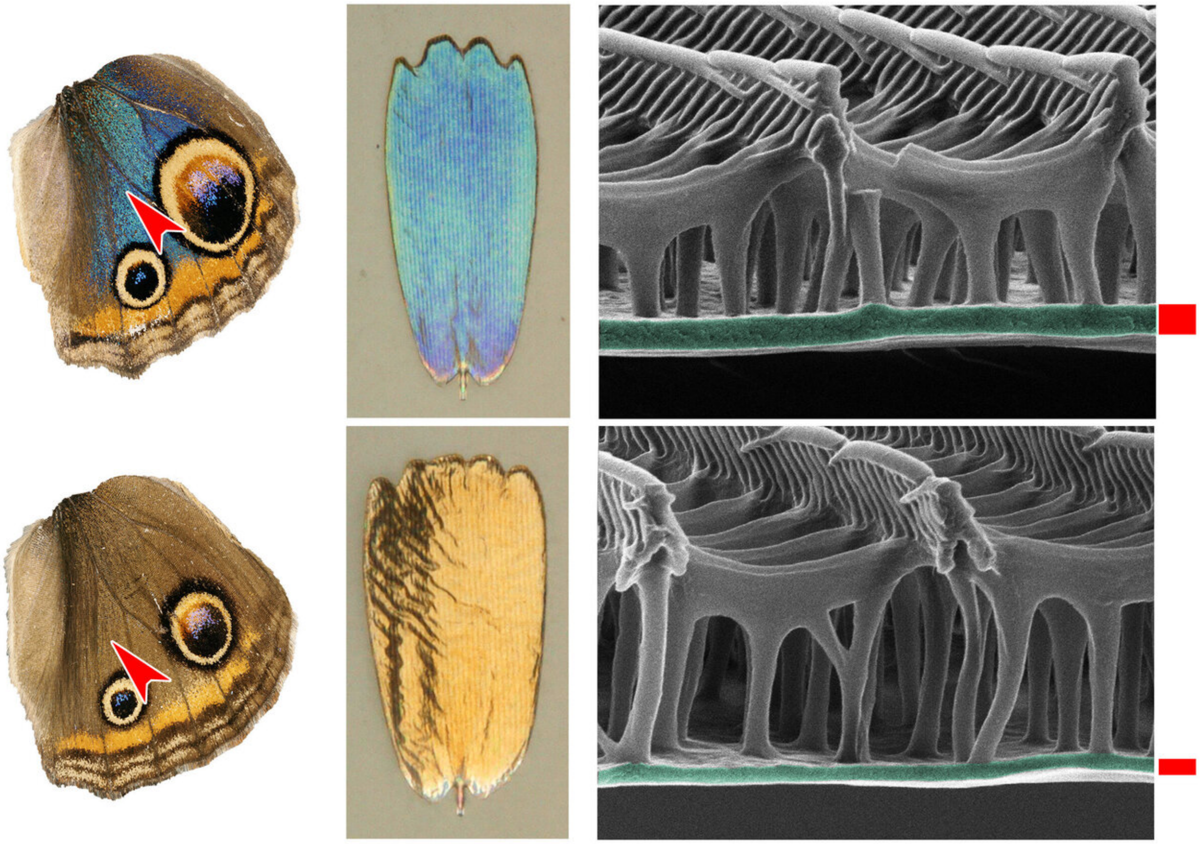
One major lesson from the study, she said, is that "most butterfly patterns probably have a mix of pigment color and structural color, and which one has the strongest impact on wing color depends on how much pigment is there."

Thayer raised both the wild, brownish Common Buckeye and the crossbred, bluer variety obtained from Smith. Using a state-of-the-art helium ion microscope, she imaged scales from the wings to see which scale structures are responsible for the color and to determine whether the color change was due to a change in structural color, or just a loss of brown pigment that allowed the blue color to stand out.

She found no difference in the amount of brown pigment on the scales, but a significant difference in the thickness of chitin, the strong polymer from which the scale is built and that also generates the structural color. In the wild buckeye, the thickness of the chitin layer was about 100 nanometers, yielding a golden hue that blended with the brown pigment. The bluer buckeye had chitin about 190 nanometers thick—about the thickness of a soap bubble—that produced a blue iridescence that outshined the brown pigment.

"They are actually creating the color the same way a soap bubble iridescence works; it's the same phenomenon physically," Thayer said.

She also found that, though the scales from the *Junonia* butterflies have an elaborate microscopic structure, structural color comes from the bottom, or base, of the scale.



The 75% greater thickness of the scale lamina from the wing of a bred blue buckeye (red bar, top row, right) compared to the thickness of a scale from the brown wing of a typical buckeye (lower panel) is responsible for the blue color. Red arrows show wing area from which scales were obtained. Credit: UC Berkeley images by Rachel Thayer

"That is not intuitive, because the top part of the scale has all of these curves and grooves and details that really catch your eye, and the most famous structural colors are elaborate structures, often in the top part of the scale," she said. "But the simple, flat layer at the bottom of the scale controls structural coloration in each species we checked."

"The color comes down to a relatively simple change in the scale: the thickness of the lamina," said Patel. "We believe that this will be a genetically tractable system that can allow us to identify the genes and developmental mechanisms that can control structural coloration."

Thayer also investigated the scales of mutant buckeyes created by Cornell University researchers that lacked a key gene, called optix, that controls color. The micrograph images demonstrated that lack of the gene also increased the thickness of the thin film of chitin in the scales, creating a blue color. Optix is a regulatory gene that controls many other butterfly genes, which Thayer will be looking at next.

"One thing that I thought was cool about our findings was seeing that the same mechanism that has recurred over millions of years of butterfly evolution could be reproduced really rapidly in (Smith's) artificial section experiment," she said. "That says that color evolving by changes in lamina thickness is a repeatable, important phenomenon."

**More information:** Rachel C Thayer et al, Structural color in Junonia butterflies evolves by tuning scale lamina thickness, *eLife* (2020). DOI: 10.7554/eLife.52187

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