Butterflies on the prowl show some color

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Sex sells. The thrum and flash of an automobile, the whisper of designer silk, the tease of a tattoo, and the ching-ching of gold chains and rings are paired in media and on the streets with come-hither abdominal tautness and the flutter of eyelashes.

It's a potent advertising mix, all to say: “Pick me.”

You don't have to look far to find correlates in the animal and plant kingdoms. Nature's showy subjects also promote reproductive success with bright colors and flash, in feathers, scales, petals and wings. So what is it about bling? With millions of years of evolution behind them, wouldn't you think butterflies would be more evolved?

It turns out that there's more substance behind all that flash and glitter than show. In a paper published in the *Proceedings of the Royal Society B-Biological Sciences*, ASU biologists Nathan Morehouse and Ron Rutowski demonstrate that butterflies have taken their colors and flash seriously, into the ultraviolet wavelengths where humans cannot see, but butterflies can, using pigments (pterins) and nanoscale structures that make human nanofabrication look downright crude – and female butterflies swoon.

“What we see as color is really a manipulation of light,” says Morehouse, a graduate student of Rutowski's in the School of Life Sciences. “We want to understand what optical mechanisms butterflies use to produce their colors. There is surprisingly little known. Part of the reason for that is that the structures used are so small, and our understanding of the way that light interacts with these surfaces at that scale is really rudimentary."

Most colors we see are pigment-based, produced through the absorption of some colors of reflected light: as in the printed material that populates our newsstands. Another way to manipulate light is through producing a physical structure that reflects specific wavelengths of light while letting others pass through, like what's seen with soap bubbles or oil slicks. What Morehouse has found is how butterflies are doing both things at once.

Butterfly wings are not flat like sheets of paper. Three-dimensional microstructures coat the surfaces of their wings – a combination of long ridges that overlay a trellis studded with beads. In some species, scientists had shown that the trellis and ridges scatter light by virtue of their structure, but they weren't able to resolve the shape or purpose of the trellised beads. Morehouse has taken understanding of these wing structures a step further. He's shown in a butterfly often seen in Arizona, the Checkered White, that the beads contain pterin pigments, and –"thanks to the quality of the confocal microscope maintained by the W. M. Keck Bioimaging Laboratory" – that the shape (like footballs) and arrangement of the beads within the trellis also lend a second structural component to the process. The combination of the pigments and their structural arrangement (semi-ordered arrays of football-shaped beads) means that the Checkered Whites' colors become brighter and more chromatic.

"Butterflies are turning out to be remarkable systems to study nanostructure and the manipulation of light," Morehouse says. "Photonics is a hot area in optical physics, which can benefit from understanding of such structures, for example for development of optical data transfer."

In terms of nanofabrication, nature has surpassed mankind for now, in structural intricacy and manufacture, producing nanostructures at body temperature and neutral pH, without caustic reagents or environmental damage and with enviable repeatability for millions of years, Morehouse says.

Is it likely that these structures and pigments arose as a result of sexual selection? Morehouse and Rutowski say “yes.”

“Female butterflies have many fewer pterin ‘footballs' than males,” says Morehouse, and Rutowski has found that females in species that are sexually dimorphic (males' and females' coloration is significantly different) are attracted to males with the highest quality color and, in some species, the brightest flash of ultraviolet light (UV).

In papers recently published in journals Evolution, Animal Behavior and Biological Journal of the Linnean Society, Rutowski, a life sciences professor in the College of Liberal Arts and Sciences, and his colleagues showed that in one species, Colias eurytheme, a sulphur butterfly, an iridescent UV coloration on males can strobe nearly 20 times a second, with the effectiveness of John Travolta and a disco ball.

So with all this inherent showiness flittering about, how is a female able to make up her mind? It turns out that all that glitters is not equal. Rutowski points out that while there is a fair amount of variability in color and iridescence among males, female butterflies can tell whose color is strongest, and whose flash is better.

“These traits are heritable,” Rutowski adds. “Offspring from the flashiest males are flashier.”

Even more intriguing to Morehouse is an apparent correlation between pterin pigments, environment (food source) and overall fitness. According to Morehouse, making pterin pigments is a very expensive process that requires a lot of nitrogen. But caterpillars in this group of butterflies often eat low-quality food – plants rich in carbon, but low in nitrogen. Both scientists point out that lower-quality food can typically translate into less color and flash.

“Pterin pigments are the most nitrogen-rich pigments described in the animal kingdom,” Morehouse says. “So the mystery is that while caterpillars eat food that isn't very high in nitrogen, butterfly wings in these dimorphic species are packed with pterins.”

Morehouse was awarded a Doctoral Dissertation Improvement Grant (DDIG) from the National Science Foundation in March to bolster his studies of the Cabbage White, Pieris rapae, and the interplay between expression of these bright colors, the underlying genetic architecture and the effects of environmental factors, such as the quality of the insects' food source.

Morehouse wonders too, how human manipulation of the environment might affect species coloration – and, potentially, species fitness.

“One of the things that we are struggling with as a society is nitrogen pollution,” Morehouse says. “Aerosols of nitrogen are being deposited in the desert from our cities. Farmers also dump much more nitrogen on fields than is actually needed. This nitrogen doesn't stay in the fields, it goes into the water systems and ends up downstream in the ecosystems. These butterflies' communication system may be predicated on a shortage of nitrogen, which allows them to make good decisions with regard to mating. What happens to them when you pump an enormous amount of nitrogen into the environment? Does it mean all of a sudden everyone looks like a hot date?”

Rutowski adds that beauty – in this case, color – truly is in the eye of the beholder.

“How butterflies see each other is enriching our understanding of butterfly coloration, how and why it is being produced, and what is it doing – in the context of our broader understanding about the function of evolution and production of coloration of animals,” he says.