Being Red

:: by skip derra

Holding up a parrot feather in his laboratory, Kevin McGraw sees more than the intertwined strands of barbs emanating from a quill. He sees evolution at work, eons of development that have made the feather the most distinctive characteristic of a bird. For example, feathers protect a bird from the elements, insulating it from the cold and heat. They also help birds stay dry in rain and snow. Lightweight, yet very strong, the feather's primary function is to help a bird take flight. Wing feathers expand the wing surface during flight, increasing lift. Relatively large tail feathers function as rudders.

But what really intrigues McGraw, an assistant professor in Arizona State University's School of Life Sciences, is the color of a feather. How does a feather obtain its color? And what does it mean for the bird? he asks.

McGraw has studied the chemistry behind the colors of many birds, including songbirds like sparrows and finches. He has studied how barn swallows judge their mates (and make judgments about their fidelity to that mate) based on color. And he has studied the chemistry behind the bright colors of parrots.

ECLECTUS

RED-FRONTED MACAW

GREEN-WINGED MACAW

BIRDS OF A FEATHER You won't find a parrot in Kevin McGraw's lab on the fifth floor of the Life Sciences C wing at Arizona State University's Tempe campus. You may even be hard pressed to find a parrot feather floating around there on any given day. "I have never even touched a live parrot that I studied," McGraw says, somewhat amused by that fact.

McGraw's research lies at the crossroads of chemistry and evolution. His interest in the color of birds with an evolutionary twist was fueled while he studied under Geoff Hill at Auburn University eight years ago. Hill has pioneered work on how birds use their color as sexual signals. He also did work on the role of diet in the color of birds. "I was really attracted to the idea that birds use color for sexual attraction," McGraw says. "I wanted to know exactly how birds became colorful, and how the colors they produce are indicators of their fitness."

The ASU scientist's interest in parrots began when he was contacted by Mary Nogare. "Mary is a parrot breeder who has a knack for asking great scientific questions," he says.

For more than a century, biochemists have known that parrots use an unusual set of pigments to produce their rainbow of plumage colors. But their biochemical identity remained elusive. With Nogare's help, McGraw uncovered the chemistry behind the colors of parrots. He can describe what is responsible for their bright red feathers—on a molecular level.

McGraw's work got a significant assist thanks to the work of an Italian chemist. The ASU researcher spent lots of time studying past experiments related to the chemistry of the pigments of bird colors. During those studies, McGraw came across the work of Riccardo Stradi. Stradi and his colleagues had analyzed the pigments in a scarlet macaw feather. They used high-performance liquid chromatography to perform the chemical analysis of feather pigments.

"Stradi studied only one feather from one bird," McGraw says. "My goal was to use his approach on red feathers for as many species of parrot we could get our hands on." During his larger study, McGraw was able to secure feather samples from zoos, museums, and pet owners. In all, McGraw says his lab has analyzed more than 1,000 samples from nearly 50 parrot species.

McGraw and Stradi are the two primary researchers in the world doing chemical analysis work in this area. Prior to their parrot studies, they had conversed via email and had even collaborated on bird coloration research. But it was only recently that the two met face to face. That meeting took place during the meeting of the International Carotenoid Society this past summer. "We met in a pub in Edinburgh," McGraw says. They sat together for a couple of hours talking about the difficulties of analyzing the pigments from yellow feathers. Stradi offered an interesting twist that McGraw is following up on in his lab.

But not all science gets done in the laboratory. Science is a meeting of minds and a sharing of ideas. It can happen anywhere. "Stradi is a boisterous Italian who speaks very little English," McGraw adds. "But he speaks Spanish, of which I know a little. So we sat in a Scottish pub, talking in Spanish about the colors of parrots while enjoying an afternoon pint."

Skip Derra

Right: A three-dimensional chromatogram obtained from parrot feather pigments. To obtain the data, scientists first grind and then dissolve feather samples in solvent. The mixture is placed into a filter column inside the chromatograph. Large, heavy molecules in the sample mixture diffuse through the column more slowly than lighter molecules. The diffusing mixture also passes through an optical measuring device. Tall peaks on the graph represent the molecules that come off the column. Peak heights indicate the amount of each molecule present in the sample. The time it takes for molecules of five different pigments to diffuse through the column is measured along the horizontal axis. Parrot species that have higher sum totals for all five peaks appear to be more red. Scientists found that relative amounts of each pigment did not show a pattern with respect to gender, species, or feather-color intensity of each parrot. The wavelengths at which the molecules absorb light are indicated along the diagonal z-axis. Each peak has a single apex. Pigments absorb the most light at one wavelength around 425 to 450 nanometers.

BLUE-STREAKED LORY

A bird's color can mean any of several things. It can signal male assertiveness within a flock, or it can be a marking of status. Knowing the behavioral context of color is important. But McGraw digs deeper. He digs down to the molecular level in an effort to understand what gives the bird its color.

McGraw uses an arsenal of high-tech equipment and methods in his lab to deconstruct the chemical makeup of a bird's feather. What he has found is both beautiful and a bit baffling. One of the ASU scientist's recent discoveries showed that a novel set of molecules are at work to create the bright red plumage in parrots. To date, no one understands clearly why these molecules work the way they do.

"We've uncovered a system where all red parrots use the same set of molecules to color themselves," McGraw says. "It is a unique pigment found nowhere else in the world. We are fascinated at how parrots are able to do this.

"There is a single set of molecules unique to and widespread among parrots. That fact suggests that it is a pretty important evolutionary novelty, and one we should carefully consider when we think about why parrots are so strikingly colorful," he adds.

What exactly is the behavioral significance of bird colors? McGraw first got interested in that question while studying color as a form of individual communication within a species. For example, many birds use color to denote status as well as to attract a mate. McGraw wanted to understand more about what makes the colors of the birds possible. Then he focused on "deconstructing the color into its component parts."

The work casts a new light on what is chemically responsible for the colors of birds. The findings defy previous assumptions and explanations for color variations in parrots. "Evolutionary biologists have not really thought hard about parrot coloration," says McGraw. "This research is exposing a whole new world of color communication in parrots and the potential physiological and biochemical roles of the new molecules we found in our work."

McGraw worked with Mary Nogare, a parrot fancier from Snoqualmie, Wash., on the study. Animals, like birds and fishes, commonly use biochromes like carotenoids to acquire red, orange, or yellow coloration. McGraw and Nogare found that these compounds, while in the bodies of parrots, are not responsible for the red colors in the parrot species they sampled.

The researchers used a chemical analysis technique called high-performance liquid chromatography to survey the pigments present in red parrot feathers. McGraw and Nogare collected and analyzed samples from 44 parrot species that have red feathers. There are some 350 species of parrots, 80 percent of which have red in their plumage.

They found a group of five molecules called polyenal lipochromes, or psittacofulvins. These molecules color parrot plumage red in all of the species studied.

McGraw says an interesting aspect of the five polyenal lipochromes is that the pigment is found only in the bird's feathers. It is found nowhere else in the body of the bird. This indicates to the scientists that parrots manufacture these molecules internally and directly at the maturing follicles of the growing, colorful plumage.

The pigments also may play a valuable role in maintaining the health of parrots. McGraw cites an independent study on the parrot pigments. Results from that study suggest that the pigments can act as anti-oxidants to quench free radicals and potentially protect cells and tissues in the body from oxidative damage.

Now, McGraw says, he's interested in learning more about the connection between the red colors and anti-oxidants within and among parrot species. He wants "to specifically explore the balance of naturally and sexually selected costs and benefits to becoming colorful."

"Parrots are unusual among birds," he explains. "Almost without exception they display fantastic colors but exhibit very little variation in color within a species—at least in colors visible to us. Parrots in general may not be using color in the classic cases of mate choice or competitive ability," McGraw says. "Exactly why they are so uniformly colored remains an interesting mystery to us—one we want to investigate.

"There is a sea of colors in birds," he adds. "Our goal is to learn why there is such a diversity from an evolutionary standpoint."

RESEARCH ON THE EVOLUTIONARY SIGNIFICANCE OF COLOR IN BIRDS IS SUPPORTED BY THE ENVIRONMENTAL PROTECTION AGENCY AND CORNELL UNIVERSITY.
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