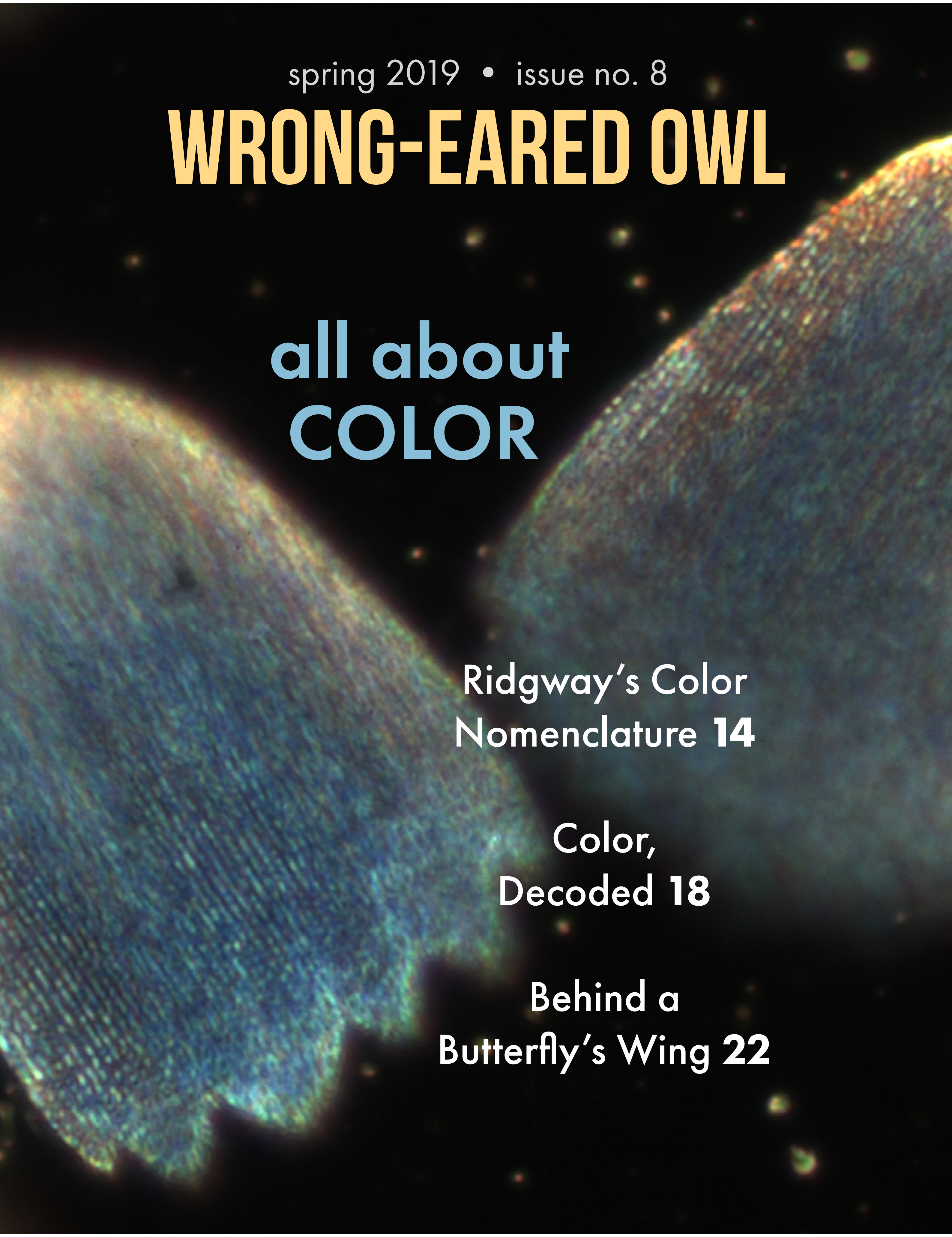
spring 2019 • issue no. 8

WRONG-EARED OWL



all about COLOR

spring 2019
exploring color

Designer, Editor
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Editor
Amaya Bechler
Editor
Cayenne Sweeney

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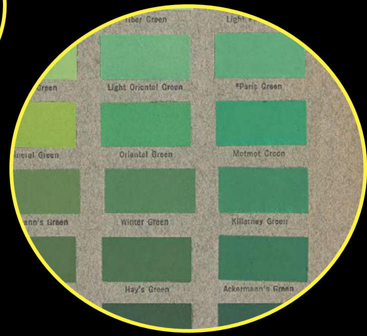

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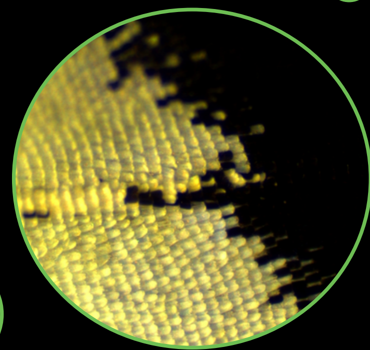
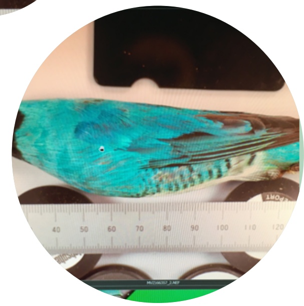


STUDENT CONVERSATIONS WITH EMMA ARULANANTHAM

INTRODUCTION

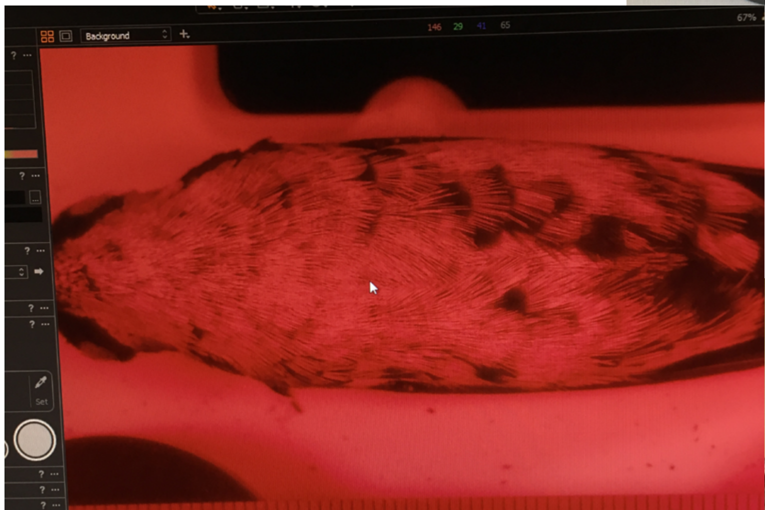
ABOUT ME I'm Emma Arulanantham, I'm 18, and I'm just finishing my freshman year at UC Berkeley. I'm currently in Molecular Environmental Biology, but I'm planning to switch majors to study environmental policy and history, specifically history of conservation. I hope to become a writer, and maybe to work in journalism, science writing, or non-profit organizations. If I continue to pursue research, I would study the effects of climate change on species' survival (particularly birds), as well as its impacts on speciation and adaptations to varying weather patterns and habitats. Currently, I'm a part-time bird-bander at the Livermore Marsh station, and I do undergraduate research at UC Berkeley in Integrative Biology in the Museum of Vertebrate Zoology.



WHAT I DO

WORK My usual work includes photographing skins of various species of birds — primarily passerines — and using a program to develop multi-spectral images which incorporate UV images with visual light images, controlling for brightness with 5% and 80% reflection standards. I will take one photograph with a regular visual lens, and then a second with a UV lens, and then combine these two images. For each specimen, I usually take 6 different photos, a ventral view, lateral view, and dorsal view, with a visual and UV lens for each. This allows us to compare color and brightness in plumage across individual birds, which can be useful in clarifying or identifying regional and geographical variation, both among species and subspecies. One example of such a species is the Fox Sparrow, which exhibits plumage variation throughout its range (and across subspecies) including difference in darkness of brown feathers, amount of ventral streaks, mottling on the dorsal side, and many other characteristics.

I think the most exciting part of this work is being able to compare and observe the thousands of specimens we're lucky to have access to in the Museum. Seeing and photographing birds up close, I notice so many details that escape my eye when birding in the field. Being able to work with this extensive natural data set of collections is amazing in itself. It's also particularly exciting to look for UV plumage in some species,



especially many species of South American honeycreepers and tanagers, because UV plumage is not perceptible to the human eye. It's like a little treasure hunt! Additionally, finding patterns of plumage difference in certain subspecies is exciting, because it could lead to new ways of identifying birds more precisely in the field, more informed taxonomic classifications, and also a better understanding of the process of speciation.

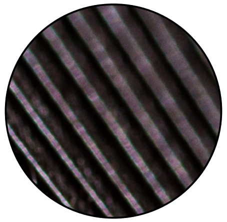
The most boring part is probably the processing (generating the multi-spectral images) which just involves clicking buttons on the computer. But the result is worth it!

CHALLENGES I would say the hardest part of my career was choosing a subject to specialize in, when there are so many exciting possibilities and career opportunities. Berkeley is overwhelmingly extensive when it comes to research opportunities, career path options, clubs, and other ways to invest your precious university time. It took me a full year to come to a decision on what I wanted to pursue, but in the end, I really appreciate that I was able to take the time I needed to experiment and test the waters of the many fields I was interested in. Another thing that is challenging about academia and the undergraduate experience, at least at Berkeley, is the competition. I'm lucky to be at Berkeley where there is a good selection of opportunities, but even so, it feels like a race to the top. Given this situation, it's also challenging to balance work and academics with personal well-being—just finding time to give yourself a break—especially through keeping up with extracurriculars or activities that may not be immediately relevant to a career, but that help us stay grounded. For me, these activities include music, exercise/time outdoors, and more generally, socializing, which all too often get overshadowed by the pressure of career success.

ADVICE I would say the best thing to do is to stay balanced—I know, vague(!), but it can really apply to almost every part of your life. Also, study what you are drawn to, not what you feel you should study—in the end, you will be more successful in doing something you are truly invested in (also something I would tell younger me). •

BIRDS (NOT OF A FEATHER)

an interview with Hein van Grouw



Hein van Grouw is a Senior Bird Curator at The Natural History Museum in Tring. For the last 22 years, the focus of his research has been the occurrence and correct identification of colour aberrations in birds, heritable and non-heritable, involving both practical breeding experiments with domesticated birds and examination of >4,500 aberrantly coloured bird specimens in museum collections. He is involved in BTO's Abnormal Plumage Survey as an 'expert' to identify reported colour aberrations. Read on to learn more about his work.

Q: What counts as a color aberration?

Hein: Every coloration/pigmentation which is different from the norm, whether it is caused by a genetic aberration (mutation), a dietary imbalance, or other external factors.

Q: What have some of the most interesting findings in your work been?

Hein: Aberrations causing white feathers (feathers with no melanin at all) in the plumage next to normal coloured feathers are often referred to as'piebaldism, or leucism, and were assumed to be heritable. However, years ago I discovered that aberrant white feathers in the plumage are often not heritable and that the causes are often unknown. More interestingly, these white feathers are not present in the juvenile plumage, and the loss of pigment can start at any time after the bird has grown its fully pigmented juvenile plumage. From the onset of the condition (the general term is 'progressive greying,' or 'progressive whitening,') the bird gains more white feathers after every successive moult.

Q: How common are heritable aberrations and how often do they become prevalent in a population? At what point do you call a population of birds with heritable aberrant plumage a "morph"?

Hein: Although certain heritable aberrations are more common than others (brown mutations are the most common aberration among birds in general), aberrations are generally rare. Interestingly, in my opinion, most colour aberrations do not affect an individual much and many do live long lives in the wild, find a partner, and produce offspring. Only pure albinos do not survive, not because they are white but because they have very poor eye sight.

"Interestingly, in my opinion, most colour aberrations do not affect an individual much."

Obviously, in smaller populations, in which the individuals are more closely related, a heritable aberration is more likely to become 'settled' into a population. A good example in the past were the black-and-white ravens from the Faroe Island. Their white feathers were the result of heritable leucism.

It's difficult to say when something should be called a recognised morph rather than an aberration. There are no rules for this. I've discussed this briefly in a paper about melanism in the past (see Further Reading on next page).

"Actively collecting birds... is a subject one can write long papers about. There are pros and cons, and a simple yes and no is impossible."

Q: Generally speaking, what is the genetic basis behind these heritable aberrations — are only a few changes in genes or gene expression responsible? Are environmental factors responsible as well?

Hein: Most of the heritable aberrations are the result of one single altered gene (mutation), resulting in, for example, a change in the melanin synthesis, or a change in the pigment distribution, or a change in the pigment cell distribution. And all these changes do have an effect on the original colouration of the bird.

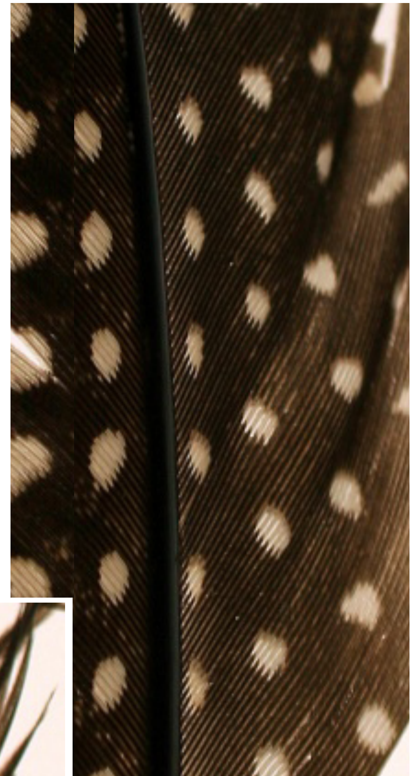
There are many different mutations, and for each mutation another, single gene is involved.

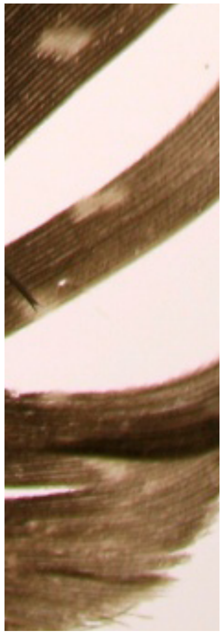
Q: Are heritable aberrations evolutionarily interesting — do they tell us anything about processes such as selection, genetic drift, etc.?

Hein: I think they are. They show us what is possible within a species, and also that certain colour patterns are often less important than we think they are in a species as colour aberrant individuals in general do survive well and do find partners and do breed.

Q: As someone who works extensively with preserved museum specimens, what is your opinion on modern-day collecting? Have you collected or considered collecting at any point during your studies?

Hein: Actively collecting birds for museum collections is a subject one can write long papers about. There are pros and cons, and a simple yes and no is impossible. Also, even if it is legal, one can ask the question whether it is ethical. In general, however, it is important to keep on adding new specimens to collections, to build up the time series for at least native species, but I think it is not necessary anymore to collect and kill birds on a large scale for museum collections. We get all our specimens via the public, bird hospitals, etc. These are all road kills, window victims, and et cetera. •

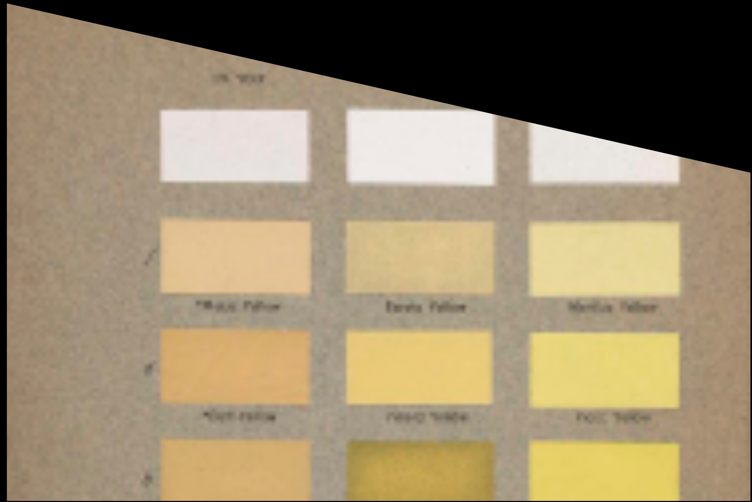




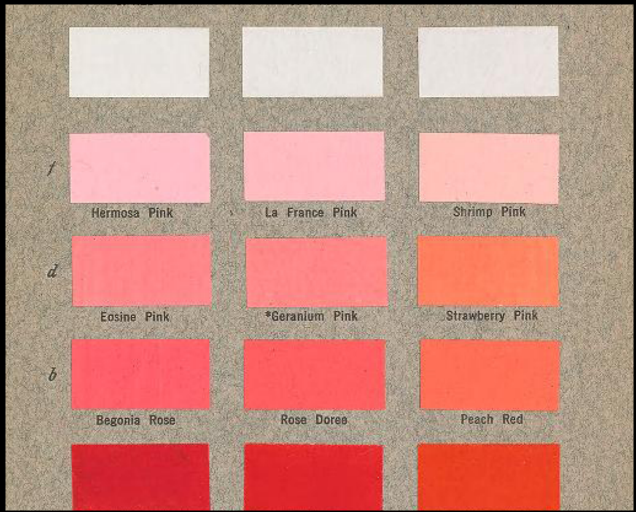
FURTHER READING

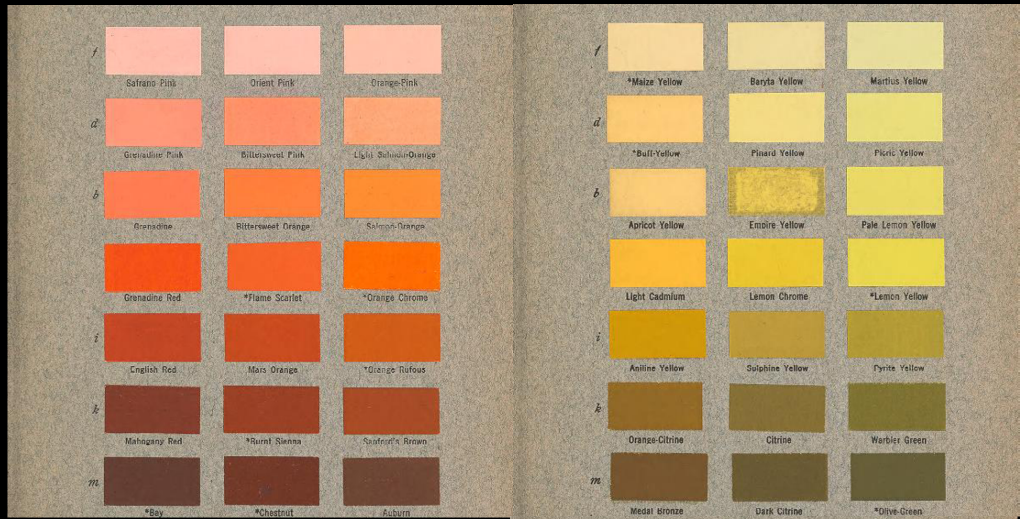
The dark side of birds: melanism—facts and fiction *link*

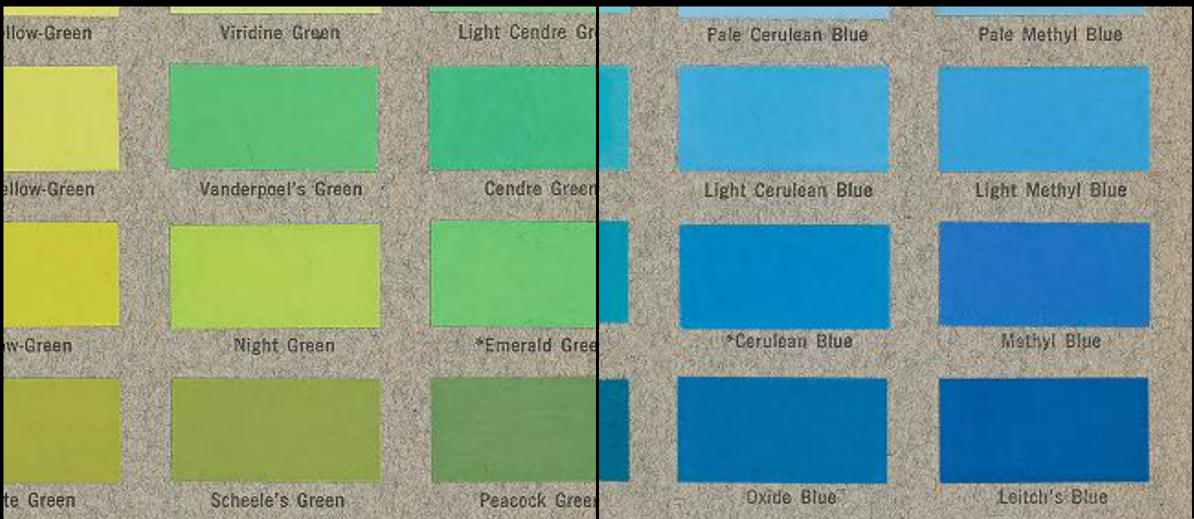
RIDGWAY'S COLOR NOMENCLATURE

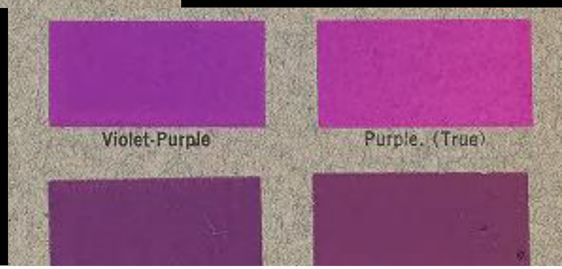


Cult classics
In 1912, ornithologist Robert Ridgway published the legendary *Color standards and color nomenclature,* a comprehensive guide of 1,115 colors that took more than 25 years to construct. Besides being rather influential, Ridgway's color guide is also aesthetically pleasing to look at. (All images here are courtesy of the Smithsonian Libraries, where the entire book is free for one's perusal).









Some names

1 Mars Orange
2 Picric Yellow
3 Warbler Green
4 Vanderpoel's Green
5 Motmot Green

Further Reading

The Bird-Based Color System that Eventually Became Pantone
hyperallergic.com

Color standards and color nomenclature
library.si.edu

AN INTERVIEW WITH ISMAEL GALVÁN

COLOR, DECODED

Ismael Galván aims to respond to the question of how the physiology of organisms constrains the way they evolve, mainly conducting studies with birds. He use the animal pigmentary system, which is responsible for the synthesis of melanins, as a study model. Read more to learn more about the biology behind the pigment found in birds.

Q: What are the main ways in which birds produce pigment and what occurs at a cellular level for each of these pathways?

Ismael: Birds possess three main types of pigments: melanins, carotenoids and porphyrins. However, only melanins and porphyrins are produced by birds, as carotenoids are photosynthetic pigments.

Carotenoids are very abundant in the plumage and bare parts of birds, where they confer brilliant yellow and red colors, but these pigments cannot be produced by birds. Instead, like most animals, birds obtain carotenoids from the plant products of their diet. Thus, carotenoids are transported by proteins to the skin and feather follicles, where they are deposited and pigment the body structures. Some carotenoids are metabolized in the liver or feather follicles, which allows changing the structure of these pigments and their color properties.

Melanins are produced by birds in specialized cells termed melanocytes that are located in the skin. Melanins produce less brilliant colors than carotenoids, but they also produce a high diversity of colors: black, grey, brown, orange, and reddish. Complex plumage patterns are almost exclusively produced by melanins. Thus, melanins are the most abundant pigments in birds. Their synthesis into melanocytes involves the oxidation of tyrosine, meaning that melanogenesis is mainly an oxidative process. Tyrosine is a semi-essential amino acid, as this can be produced from a precursor amino acid (phenylalanine) but can also be taken in through the diet.

Porphyrins are pigments that are produced by virtually all cells as intermediates during the synthesis of heme. Porphyrins are not deposited in the integument and thus do not contribute to the external coloration of animals. Birds, however, are an exception, as these are the only organisms able to deposit porphyrins in the integument. Only a few groups of birds are known to deposit porphyrins in feathers, notably bustards, owls and nightjars. Porphyrins are very prone to degradation under exposure to sunlight, and this is the reason why it was thought that porphyrins did not confer conspicuous colors to the plumage of birds. Only the fluorescence that porphyrins produce when illuminated with UV light revealed the presence of these pigments. Recently, however, we discovered that porphyrins produce brilliant red coloration in the base of feathers of bustards, but this color disappears in minutes of exposure to light.

Q: How similar are these color synthesis pathways to other vertebrates?

Ismael: These pathways are similar in endotherms (birds and mammals), with the notable exception that only some birds are able to color their external body with porphyrins. Also, mammals cannot use carotenoids to color their body, with the exception of a bat (the Honduran white bat). Regarding other vertebrates (fish, amphibians and reptiles), they pigment their bodies with melanins like birds and mammals do, but they possess different types of cells that provide them a high flexibility in combining pigments and sometimes producing rapid changes in coloration by contracting and expanding these cells.

Q: Describe your research. How many specimens did you analyze? What tools, software, or equipment did you use? How long did it take?

Ismael: In my study entitled "Complex Plumage Patterns Can Be Produced Only with the Contribution of Melanins," we examined more than 9,000 illustrations of birds in specific books, comprising the entire class Aves. We did not use any specific software, as the aim was to identify the presence of complex plumage patterns. For this, we defined a complex plumage pattern as a combination of two or more discernible colors that occur spatially more than two times uninterrupted. It took about six months to examine all illustrations.

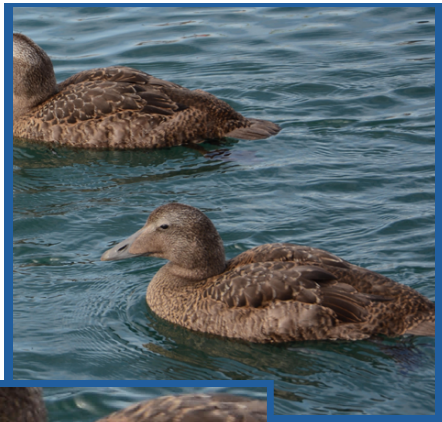
Q: What were your findings? Were there any exceptions? What are the implications?

Ismael: We found that complex plumage patterns are present in about 30% of species. Among those, 98% are species in which complex patterns are made of colors that include colors produced my melanins. The exceptions (2%) are species in which melanins do not contribute to the formation of complex plumage patterns. These exceptional species belong to only three families of birds: Ciconiidae (storks), Columbidae (pigeons) and Cotingidae (cotingas). The functions of complex plumage patterns in birds are not fully understood, but our study implies that these functions will necessarily be related to the synthesis of melanins.

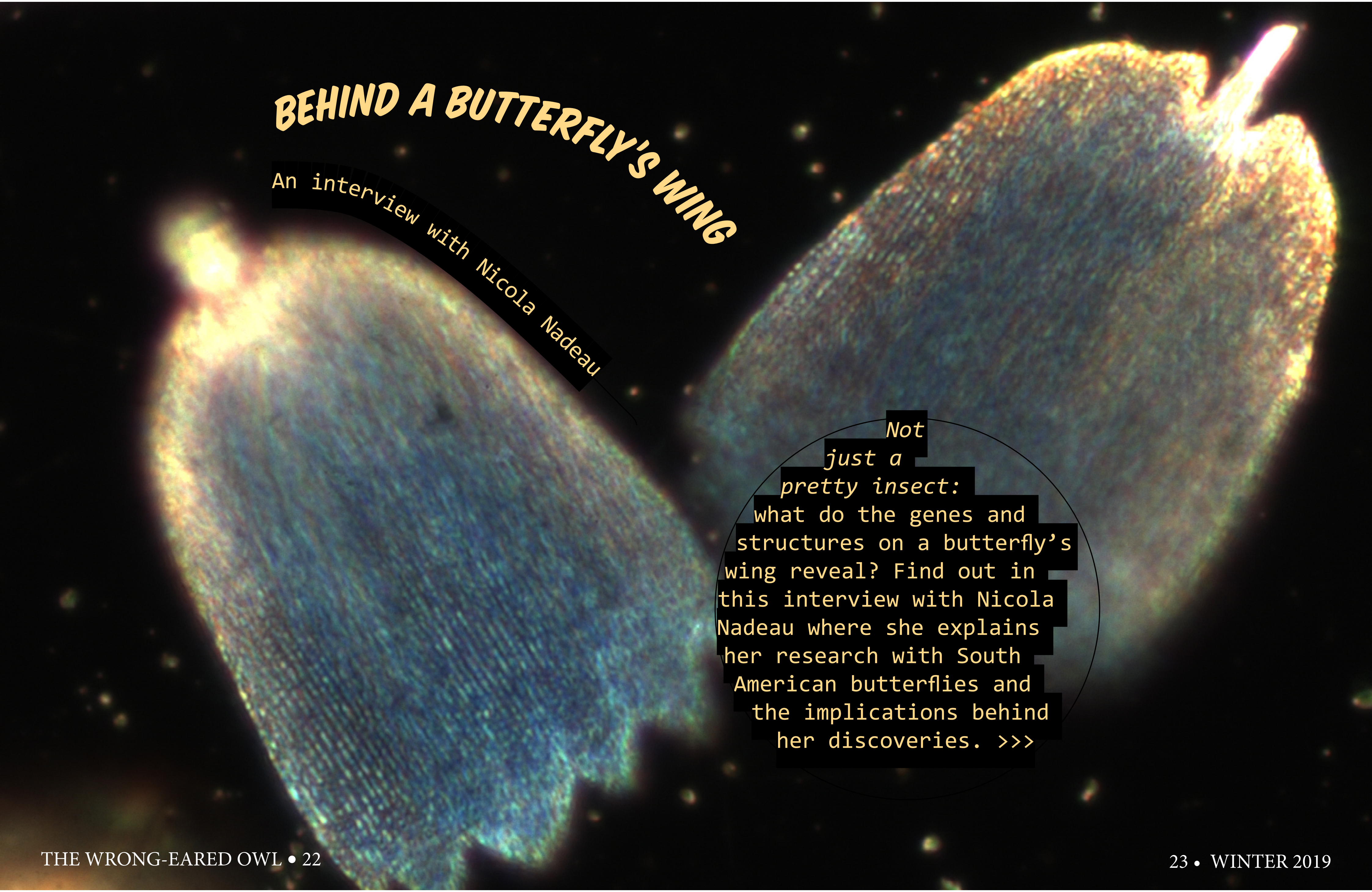
Q: Do you have any advice for aspiring ornithologists and researchers?

Ismael: I would encourage them to consider contributing to the advance of ornithology. Like any other area in biology, this can only be achieved with an interdisciplinary approach. Biology is a combination of chemistry and physics. To take advantage of the amazing model that birds represent, it is advisable to see the natural history of birds from the perspective of the underlying chemical and physical processes. 'Integrative ornithology' is the term for this. •

***Ismael Galván** conducted his doctoral studies in 2004-2009 at the National Museum of Natural Sciences, CSIC, in Madrid, Spain. Then, he studied at the University of Paris-Sud 11 (France) and at the University of Lisbon (Portugal) before returning to Spain to lead a research group on evolutionary physiology at the Spanish National Research Council (CSIC).*



Top right: *Common Eiders (Somateria mollissima), Iceland. The other photograph shows a Black-mandibled Toucan (Ramphastos ambiguus), Costa Rica. Copyright Ismael Galván*



BEHIND A BUTTERFLY'S WING

An interview with Nicola Nadeau

Not just a pretty insect: what do the genes and structures on a butterfly's wing reveal? Find out in this interview with Nicola Nadeau where she explains her research with South American butterflies and the implications behind her discoveries. >>>

Heliconius erato and melpomene with blue structural colour (credit Melanie Brien)

Heliconius erato without blue structural colour (black) (credit Melanie Brien)

Heliconius erato and melpomene with blue structural colour (credit Melanie Brien)

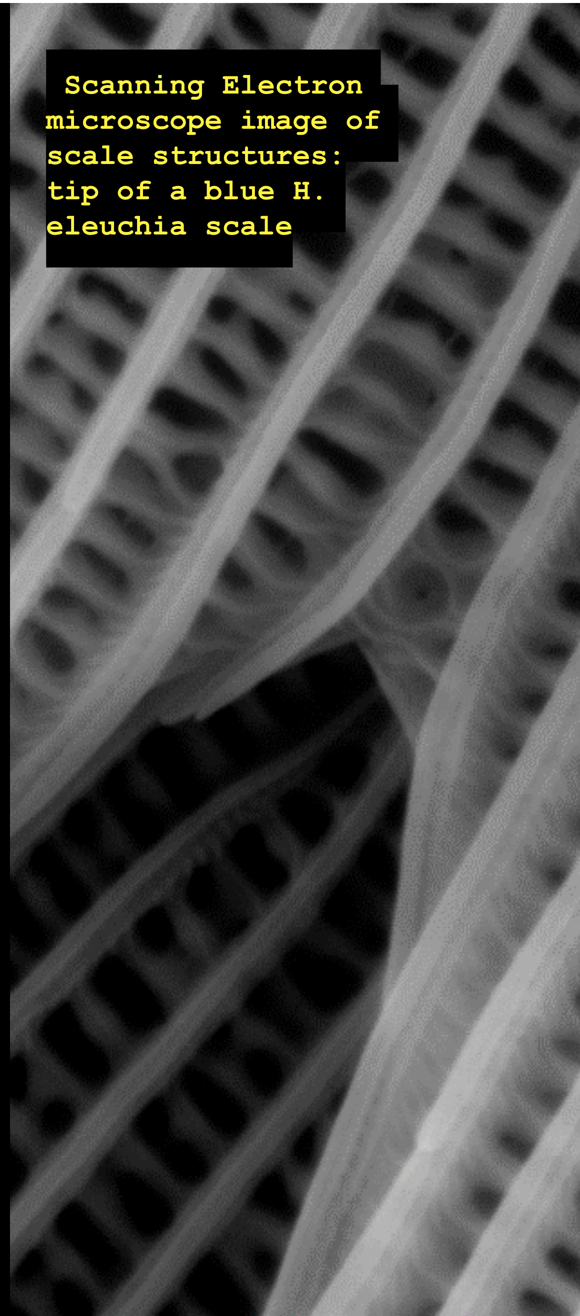
Q: What's your latest research project? What are some of your favorite findings from your research overall?

Nicola: There are two main research projects that I'm working on at the moment. One is trying to understand how structural colours form on butterfly wings. Structural colours are produced by nano-scale structures, of a similar size to the waves of light, which selectively reflect certain wavelengths. The vast majority of blue and green colours in animals are structural, as are any colours that change with the illumination or viewing angle. The nanostructures that make these colours need to be very precise. Despite being widespread, very little is known about how these precise nanostructures are formed by animal (or plant) cells. We're working on a group of butterflies from South America, in the genus Heliconius. The Heliconius butterflies have black, red and yellow colours that are due to pigments, but some species and sub-species have a shiny blue or blue-green colour that is due to scale nano-structure.

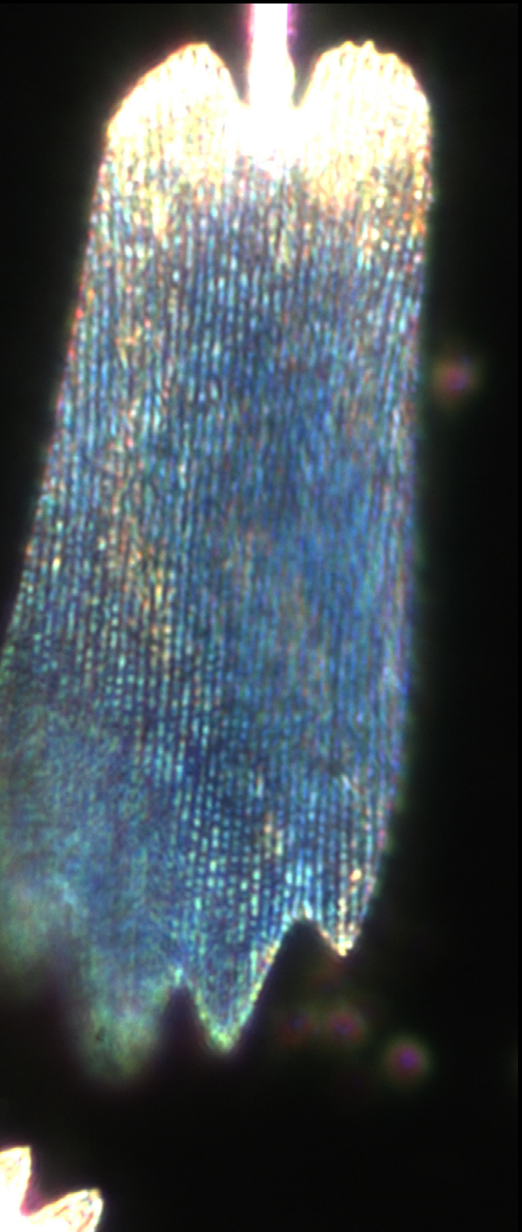
The difference between a black and blue scale is the shape of the ridges on the scale. Blue scales have ridges made up of several layers, while on black scales the ridges are curved and not layered. We are working to identify the genetic differences that make the scales either blue or black.

A more recent project, which we started less than a year ago, is investigating adaptation to altitude in Heliconius butterflies. These butterflies occur from sea level to over 2000m in the Andes. We are working on how they have adapted to the different environmental conditions across this gradient.

Like picking between one's children, it is hard to pick a favourite research result. The results I have got most excited about were probably during my PhD, maybe because research was still so new and exciting then! The main project in my PhD was investigating the evolution of genes involved in producing, or regulating the production of melanin. I was looking at the rate of molecular evolution of these genes across the Galliforme order of birds. This group contains birds like the peafowl, where the males have very elaborate plumage, while the females are fairly drab, as well as species like the partridge, where both the males and females are fairly drab in colour. I found that one



Scanning Electron microscope image of scale structures: tip of a blue H. eleuchia scale



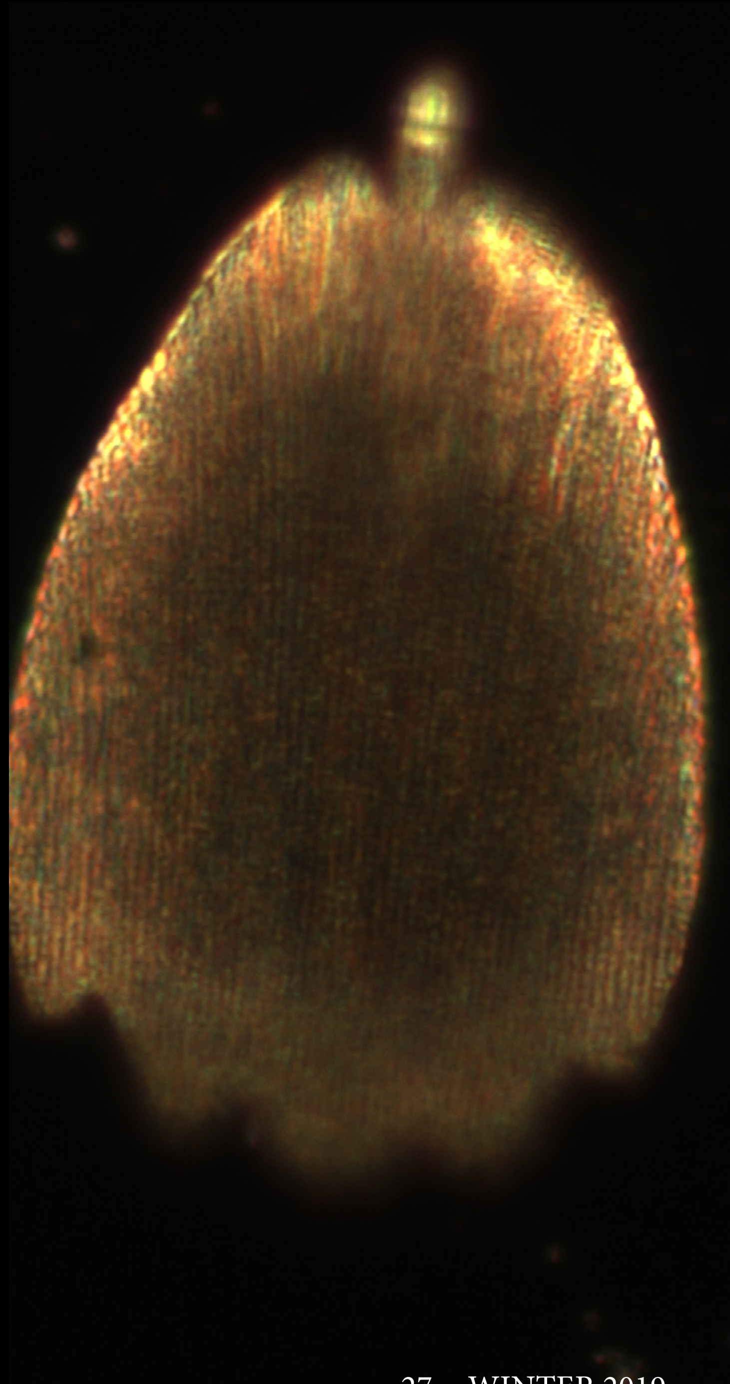
called MC1R (or the melanocortin-1-receptor), showed more rapid evolution on several branches of the evolutionary tree of the Galliforms where the male plumage colour was very different to that of the female. This result was exciting because it not only showed that we could identify signatures of sexual selection at the molecular level, but also that a single gene could be repeatedly targeted by selection, even when producing quite different plumage colours.

Q: What research techniques do you use to identify genes involved in production of color?

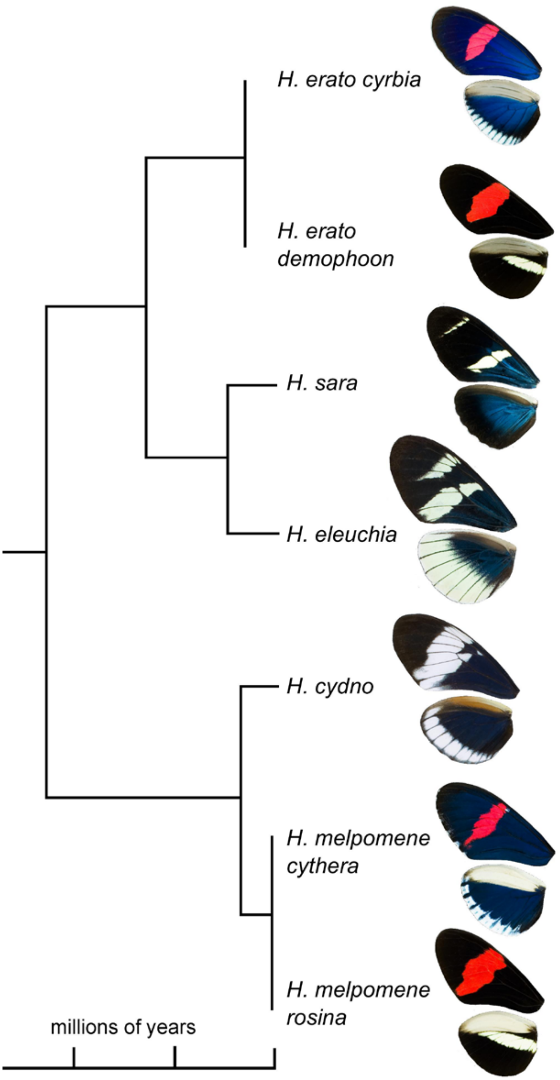
Nicola: At the start of my PhD the chicken genome had just been published. This was part of the motivation behind the project because this was the first bird genome and the first time that (almost) all the genes in the bird genome where known. However, at that time it was still unthinkable that a whole genome could be sequenced within the scope of a PhD, so my work focused on identifying genes that seemed like interesting candidates (mainly from what was known about them in mammals) and investigating what they did in birds. Within about the last 10 years that has been a massive shift in what it is possible to sequence, due to the development of new sequencing technologies. This means it is now fairly easy to get information on the complete genome sequence for hundreds of individuals and species. We are using this to sequence the whole genome of large numbers of individuals to identify parts of the genome that are different between butterflies that are different colours, or that live at different elevations.

Q: What difficulties, if any, do you encounter in collecting and interpreting data?

Nicola: Getting to the butterflies themselves is the first challenge. For the structural colour project we had to get to the region between Colombia and Panama where the black and blue butterfly subspecies meet and hybridise. This is a notoriously difficult place to access, but at the same time meant that we got to go to some very remote and beautiful places. Interpreting whole genome data is also challenging, because there is so much of it! We often have several terabytes of data, which is a challenge just to store and handle, but also means that we can't



Tree showing Heliconius with and without structural colour



physically look at all of it. Instead we need to rely on computational methods to summarise it and find interesting parts of the genome. We also need to be aware that there are lots of things that can cause parts of the genome to be different between populations. This can include things like selection acting on other traits or just neutral genetic drift, where genetic differences can accumulate randomly, if the level of interbreeding between the populations is not very high.

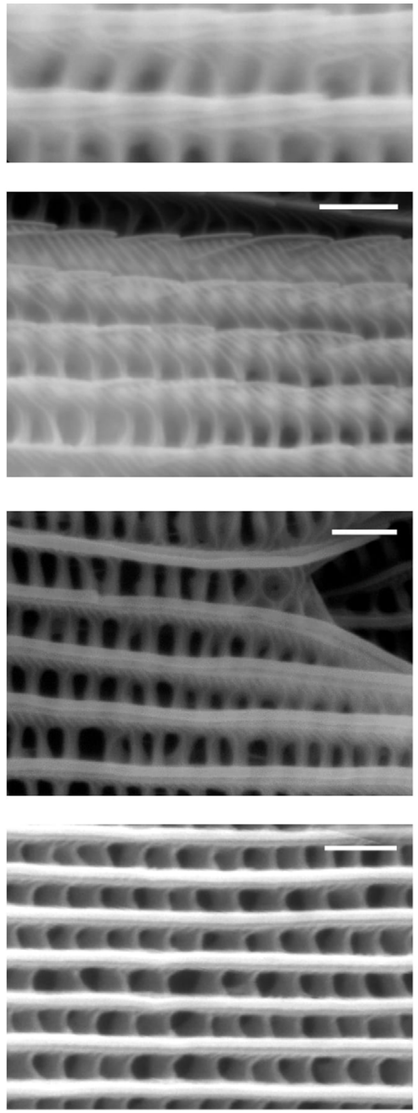
Q: How many genes are typically involved in color production?

Nicola: We know that there are lots of genes involved in making animals and plants the colours they are. These include enzymes that are need to produced pigments, signalling genes that are needed to make sure the pigments are made in the right place to give a particular pattern, and genes that we don't fully understand yet, that are needed to make structural colour.

However, one thing that my research, and that of others, commonly finds is that when evolutionary changes in colour happen these are very often produced by a change in just one or two genes, which can have a major effect on the appearance of the animal. This is the case for the MC1R gene, I studied during my PhD. In many vertebrates changes in this gene are responsible for producing darker or lighter coloured individuals, often to camouflage them in a new environment. In the Heliconius butterflies we have identified five genes that have been repeatedly targeted by natural selection to produce changes in the pigment patterning on the butterflies' wings. On the other hand, for structural colour in Heliconius this doesn't seem to be the case, and we find that changes at several genes are need to produce the black to blue shift.

Q: How prevalent is convergent evolution in butterfly wing colors?

Nicola: One common cause of convergent evolution in butterfly wing colours is mimicry. This can either be when a palatable species converges on the colour pattern of a toxic species in order to gain protect from predators, or several toxic species can also often converge on the same wing colour pattern. The latter is less intuitive, but it benefits all the toxic species by being easier for the predator to learn a single



Scanning Electron microscope images of scale structures pattern, rather than having to learn lots of different ones. It is hard to put a number on how prevalent this is but it does seem to be more common in the tropics than in temperate regions. Virtually all Heliconius species have a mimetic relationship with at least one other species, normally also within Heliconius.

Q: Overall it seems convergent evolution is more prevalent than a lot of people once thought. What do you think should be the next step to study in this particular area of evolutionary biology?

Nicola: I'm not sure that convergent evolution is more common than we thought, but it does seem to be the case that convergence at the level of the genome (repeated evolution of particular genes) is more common than we might have imagined. One, previously underappreciated mechanism by which this can happen is sharing of genes between different species. People used to think that species were fixed entities and never exchanged genetic material, but it is becoming increasing appreciated that even fairly distantly related species can and do hybridise occasionally. This means that they can exchange the raw material of adaptation, genetic variants, and also that these variants have often already evolved for a particular function. When these variants find themselves in a newspecies they can then sometimes allow that species to adapt in a new way. I think this is a really exciting new area of evolutionary biology.

Q: Do you have advice for students who are interested in entering the same topic of study as you?

Nicola: Study hard and read books but also be sure to get outside and experience nature. There is no substitute for seeing animals in their ecological setting to give you insights into their evolution and adaptations.

Nicola Nadeau *was born in Scotland, UK. She did her undergraduate degree at the University of Newcastle-upon-Tyne, and her PhD at the University of Cambridge (UK). She was a post-doctoral research associate in Cambridge for 6 years before starting her own research group at the University of Sheffield in England, UK, where she is now a lecturer (assistant professor).*

Mimetic butterflies, Heliconius erato (top) and Heliconius melpomene (bottom). Butterflies from Ecuador have a structurally produced blue colour (left), while those from Panama do not (right).

Elisa Yang is an incoming sophomore at UC Berkeley who plans to research evolutionary biology and its relation to anthropogenic change. She started *Wrong-eared Owl* in 2017 as an oppurtunity for students and young birders to have an outlet for creative control.

Amaya Bechler is a birder from Humboldt County in northern California. She is entering her senior year in high school and plans to pursue a degree in biology afterward. In addition to regular birding, she enjoys learning to band birds at a local banding station, and collecting data on birds for a research project. She's also interested in writing and illustration.

About the Contributors