Avian Blues

Lately, I've been thinking about eyes, always first in green and gold that sing to passion and warmth, walks and rain, a glancing touch, electric, but then unbidden or resolved, I flit like a drowning man to a watching bear or the dead glass eyes of my father's deer staring in a commanding sweep across the room. Finally, my thoughts begin to rest in an azure sky filled with wheeling birds. They come closer and then stop in mid-flight and in a myriad of colors, but only the blue is singing today. There are blue eyes, and blue skin. Some have blue feathers and I begin to wonder what, how, and why. Yes, I think of advertising fitness. That's surely some or all of the why but then there is the what and the how.

We have seen double-crested cormorants on a few occasions on the bird walk, usually as a singleton or in a small, determined flock flying in a straight line, always at a distance, and never during breeding season. Their eyes, had they been close enough to gauge, would have exhibited an apparently sexually unattractive dark pool of black. Skip over to the coast where these birds tend to breed in the late Spring or early Summer and an entirely different view can emerge. The eyes become blue or blue-green during the breeding season. The inner mouth becomes an intense bright blue (Fig.1). Both of these affectations are seasonal indicators signaling fitness to potential mates. That said, great eye color is necessary but insufficient. First-year birds can also display striking eye colors during the breeding season, but no adult female double crested cormorant is going to mistake a bird with semi-adult plumage and no crests for a worthy mate, no matter how enthusiastic he might be.

Blue eyes and skin are not especially common in birds but there are examples beyond the double crested cormorant. The chicks of American crows and common ravens, both bird-walk corvids, have blue eyes. I've only seen this once in real life. Prior to the West Nile virus epidemic of 2003, which wiped out our neighborhood crows, we sometimes had crows nesting in our yard. One day, a crow chick falls out of his nest. He survives the fall and gives me a rather baleful pale blue-eyed look when I happened upon him. I decided not to eat him, but I don't think he made it through the night. Had he stayed in the nest, his eyes would have turned brown, by the time he fledged, and, eventually, black as an adult. Humans occasionally have a similar response, with a blue-eyed baby whose eyes eventually yield to brown, hopefully without causing any parental discord in the interim.

Fig. 1. Double crested cormorant showing blue eyes and mouth. Ruben Giron

Blue skin patches also occur in some bird species beyond cormorants. Turkeys (not a bird walk bird) have a prominent blue throat patch during the breeding season and the great blue heron, which is an occasional visitor to Caltech, develops blue lores (the area between the eye and the base of the beak; see Fig. 2). There are, of course, many birds with blue feathers, including the scrub jay and western bluebird, both prominent, at times, contributors to the bird-walk.

Fig, 2. Great blue heron with blue lores, Thomas Claud

So, blue is a well-established part of the color palette for some birds, but that begs the question of how they make a blue work for them. There aren't a lot of natural blue pigments and birds don't use the few that are available. Yet their use of blue is widespread, which means that there has to be a trick. I'm mulling this over and it is at this point that I sense behind me the ghost of John Tyndall. "It's all an illusion", he whispers into my ear, which seemed an odd thing for him to say as he was all about seeing through an illusion, not imbibing it. I don't normally talk to dead physicists, but I have a really soft spot for elegant experiments that illuminate basic phenomena and Tyndall was full of them (look into some of his experimental work on magnetism, if you'd like a taste). I just couldn't help myself. "Could you show me the experiment", I asked. He had done or supervised thousands of experiments in his career, but Tyndall knows which one I want (my figments are very sensitive). A glass cylinder appears. Smoke flows into the tube, calms, and then a bright collimated light is beamed down the center of the tube along the long axis. Big deal? Yes!! If you look at the cylinder from the side (i.e. perpendicular to the long axis), it's blue! Look at it from the end of the tube and the color is red. The original yellow light is gone. So, what happened? The smoke is composed of small particles, averaging 10 or 20 nm in diameter for cigarette smoke and perhaps an order of magnitude larger for the Eaton Canyon wildfire. I don't know what Tyndall used for the smoke (he didn't tell me), but his smoke particles were sufficiently close to the wavelength of visible light (~380-750 nm) so that shorter wavelengths (blues and violets) were effectively scattered off their original path, but the longer wavelengths (reds and oranges) were not. If the particles had been too big, they would have scattered or blocked all wavelengths equally and there would have been no preferential separation of colors. If particles had been too small, there would have been no scattering and, therefore, no separation of colors. In fact, this phenomenon was used by Tyndall and others to characterize the concentrations and sizes of particles in a sample of gas.

For a blue-obsessed bird, the key is to acquire a medium containing particles of the right size (there are also some shape effects) and then let sunlight do the rest. Both we and birds play a similar game. For an eye, light enters and encounters the iris, which contains small particles that scatter the blue, but let the higher wavelengths pass through. The residual light then strikes a melanin-bearing layer. Melanin is a brown pigment. If the residual light is all absorbed, you are left with only the scattered blue coming out of the iris. You have blue eyes. Reflect some of the residual light back through the iris and out the eye to mix with the scattered blue and you can generate greens and yellows. If you have a deep melanin component that reflects, it can dominate, yielding brown eyes. A similar game works for the blue skin of birds. Fill a near-surface layer of skin with suitably sized particles of fats or proteins and you can generate blue skin. If you can't make and store those little fat particles, your color will be off or absent and you are probably not going to be viewed as a desirable mate.

Blue (and green) feathers are also constructed to take advantage of scattering. If the barbs of feathers have air pockets in the right size range, they can scatter light and separate out the blue end of the visible light spectrum. If the melanin backing within the feather absorbs the remaining incoming light, the result is blue and you have a blue-colored bird. Let some of the residual light back through to mix with the blue and you can generate a green. Welcome to your local parrot or parakeet.

So, here's a trick for your precocious child or grandchild. Take a blue (or green) feather and have him/her look at it and tell you what the color is. Easy, right? Now, have him/her shine a flashlight through the feather so that the light, instead of being reflected off of it, which is what the bird would want you to see, is coming up through the feather. The melanin now talks and says that the feather is brown or perhaps a muddy gray. Try it with a white feather. There is no significant change in apparent color. You will likely see some yellow from the flashlight beam coming through, but the feather isn't going to suddenly change to red. Try it with a brown feather and you won't see much change. Black? Here, you will probably see some brown working through, and this could lead to a discussion of pigments in general and of melanin in particular   So, what is going on with those blue or green feathers? It’s a great puzzle for your kid, but my Tyndall ghost was right. It’s all an illusion.