Ask-a-Biologist Vol 015 (Guest Kevin McGraw)

Roses are Red and Violets are Blue, but Why?

What is color? Do all animals see color? Do all animals see the same colors? In this show we learn the answer to these questions and about the colorful research that ecologist Kevin McGraw has been doing with birds and their colorful feathers. We even learn how the color “red” plays a special role for many animals including humans.

Transcript

Dr. Biology: This is Ask A Biologist, a program about the living world, and I am Dr. Biology. Look around you. I bet you'll find reds, greens, blues, and yellows--just a few of the rainbow of colors you see each day. But what is color? And just how do animals see color? Today, we get a chance to sit down with a scientist that is very interested in animal coloration, and in particular, how birds see and use color.

Our guest scientist is Kevin McGraw, who is a professor in the School of Life Sciences at Arizona State University. Dr. McGraw is a behavioral ecologist that spends a lot of time researching how birds--brightly colored birds, such as many of the parrots you might see in the rain forest use color in their daily lives. He's also interested in one particular color: the color red. In fact, I think what you'll learn today about colors and the color red might just surprise you.

Right now, let's welcome our guest. Thank you for joining us today, Kevin.

Professor Kevin McGraw: Thank you for having me.

Dr. Biology: Let's jump right into it. Let's start with a basic question: what is color?

Kevin: Well, in its most simple form, color is light. The sun, and a variety of other light sources, put out a rainbow of waves of light that are transmitted through the atmosphere and bounce off of surfaces, and come to our eyes as different colors. If a substance, or surface, let's say, reflects a lot of red light, it is received by our eyes as a red color.

Dr. Biology: That light, we can use a term called photons, just in case it creeps in later on when we're talking. So why is a green leaf green, or the sky blue?

Kevin: Well, things are colored based on their properties. And they can be either chemical properties or physical properties. In essence, things are colored because they reflect light at particular wavelengths. So a leaf is green, again, because it reflects green light. The sky is blue because it reflects blue light.

Now, to get even deeper into it, there are chemicals, or particles, in each of these things--the leaf or the sky--that, again, are reflecting. And so in a leaf, there are a variety of pigments that are absorbing light--namely chlorophyll and arytenoids, which play a role in photosynthesis, or energy harvesting in plants. And they, in turn, absorb all of the light, except for green, such that that light left behind--to be reflected and seen by our eyes--is in fact green.

The sky is blue for a different reason. The sky is filled with numbers of very small particles that are arranged as such to scatter light at very, what we call short wavelengths. And we'll come to know that the shorter the length of the wave of light, the more blue or violet it gets, just like that end of the rainbow. And so we, then, look up and see the sky as blue.

Dr. Biology: And the other side of the rainbow is up in the reds.

Kevin: That's right, the typical ROYGBIV: red, orange, yellow, green, blue, indigo, and violet.

Dr. Biology: Very good. I'd like to mention one experiment, or observation, that you could try at home. This is with milk. You could go get whole milk or cream, you could get two percent, and you can also get skim milk. And if you'll pour them in a clear glass, what's kind of fun is you can observe what they look like. In other words, what colors do you see?

And I think you might notice there is a difference. And then what you have to do is think, "Why are these different?" Some of them are going to look much whiter, and some of them are going to look a lot bluer. I'll leave it at that, and if you have questions, you can always send it in to Ask A Biologist.

Well, we've learned about what color is, and we've learned a little bit about why certain things are certain colors. How are we able to see color?

Kevin: Well, we, and most other animals, see color with our eyes, and we see color with our brains; and I'll explain what I mean by both of those. In the eyes of animals are particular cells that are sensitive to light. We call these rods or cones. Rods, for example, are the cell types that are found in our retinas, which are really sensitive to the intensity of light, not necessarily specifically to what waves or wavelengths of light are out there.

In turn, there's the other type, which are the cones. The cones are sensitive to exactly the types of waves of light--the red, oranges, yellows, green, blue, indigo, violet--and so they are truly the color capturing cells. We have particular types of cones, in our eyes, which allow us to see three main types of color. We see red, green, and blue, and everything in between are combinations of the sensitivity of the different red, green, and blue photoreceptors, or cells.

These cells, in turn, are part of a nervous system that are connected to parts of our brain through one specific nerve, called the optic nerve, which then connects to parts of our brain and essentially communicates to us exactly what a color is. And that's the term "color sensation" or "color perception" which is very different from the term "color reception" which is exactly what light wavelengths are received by our cells.

And this study, this area, of color sensation or perception is a very deep and rich one--one in which fields of neurobiology and psychology can contribute. And really, only within the past few decades have we really been able to scratch the surface and understand, really, what it means in our brain to construct the image of blue or red.

Dr. Biology: We can see colors, using the cones. At night, it's kind of curious. Just go outside when it's really dark, and you have this low light; see if you get anything in color. And I'll bet, unless it's got a bright light on it, you won't see color, because the only things that work are the rods, at that point.

Kevin: That's right.

Dr. Biology: Do all animals see the same colors, or do all animals see color?

Kevin: Absolutely not. Animals differ in the types of, again, these cones that they have, not only the numbers of them, but also the specific area of this electromagnetic spectrum that we receive from the sun to which they accumulate most light.

Birds, for example--the organisms that I study--are sensitive to four different areas of the spectrum. So whereas humans, again, see in three main colors, birds are actually sensitive to red, to green, and to blue, as well as to either violet or ultraviolet light--which, of course, we view as something that is damaging to our skin, or something from which we need to protect ourselves.

And yet, birds see this, coming from the sun, reflected from surfaces, and it completely enriches their visual experience--much more so than, say, even ours, which we would see as quite rich, in the group of animals that we are, the mammals.

Dr. Biology: So how do we know animals see color? Or for that matter, how do you and I know we see color the same way?

Kevin: Well, some of the most basic research can be used to test their behavioral sensitivities. You can present animals with a variety of color patterns, let's say, in association with, maybe, some food, and look at the degree to which they can sense, or discriminate, certain variations in color. You can also get more sophisticated machinery involved in testing color sensitivity.

You can do physiological experiments, where you can actually shine light into the eyes of various animals, and look at the extent to which those cones in the backs of their eyes, on the retina, actually respond to and fire as neurons, in response to, let's say, red light or orange light or yellow light. So we have with us, yeah, a series of different methods that we can use to test color.

Now, actually knowing the true color sensation gets into a whole different psychological realm. As humans, we can discuss it. We can say, "Dr. Biologist, I see blue. What do you see?" And if you say "blue" we can come to some consensus that what we're seeing is, in fact, consistent between individuals.

Now, to get a dog or a cat to communicate to us that they see blue like us is obviously a whole different challenge. And so that's where the idea that what we see as blue or they see as blue becomes much more behavioral and physiological types of investigations, more so than conversations.

Dr. Biology: Yeah. It's a little hard to talk to the dog and have the dog at least talk back, right?

Kevin: [laughs] exactly, yeah.

Dr. Biology: You have some very color research; or I should say, your research subjects are very colorful. What have you learned about brightly colored birds?

Kevin: Well, in one sense, brighter is better. There's a group of birds out there--finches and sparrows, namely the northern cardinal, which is so common of a backyard bird in many of our feeders. Those birds tend to be very brightly colored in a method of communication between individuals.

Those individuals that are more brightly colored, and a more rich red, are actually better mates and of better quality. And this has to do with the type of pigments that they use to become colorful, and in turn, how those may be limiting, or linked, to certain aspects of, say, their diet or their health.

Dr. Biology: There are other animals that also have bright colors. Do colors perform the same role for all of them?

Kevin: No. By no means is color conserved in all ways across the animals. Even beyond birds, animals are using color for blending into their environment, so that they don't want to stick out and communicate and signal to other individuals. So it's an anti-signal in a sense, a hidden signal.

In other cases, animals don't necessarily need to display anything about themselves as a mate or their quality. But they're simply of a particular color in order to say what sex they are, or should I say, what gender they are, or the extent to which they are a member of a particular species, so that they can ensure that they mate with their species and recognize themselves different from another species with which they wouldn't necessarily want to exchange their genes.

So there's a whole suite of things that animals can to talk to one another about, essentially, with their colors.

Dr. Biology: Yeah. Actually, I've seen, in many shows, and talked about the fact that there are quite a few animals that are brightly colored, and it's basically warning: stay away.

Kevin: That's exactly the case. You don't see it very often in birds. There's one group of birds from New Guinea known as the pitohuis. The pitohuis are a brightly colored group, and their bright coloration indicates that they're toxic. They actually eat ants and store up the toxins in ants.

And then, by being brightly colored, potential predators can learn very quickly, if they take a taste of that bird and they get a very noxious, or unpleasant, taste in their mouth, by all means, they'll learn that that's a brilliant, avoidable animal that they will not want to confront as a prey item in the future. Interestingly, their named as such the pitohuis because the native New Guineans, when they spit out the toxic bird, they'd say, "Pitohui!"

Dr. Biology: [laughs]

Kevin: Of course, beyond birds, there are a whole slew of other noxious butterflies, or toxic lizards, amphibians--for example, frogs and salamanders--that are really richly colored red or orange. And again, that's a memorable imprinting experience that any predator might get when it tries to lick or taste one of those food items.

Dr. Biology: Right. Actually, some of them are rather poisonous, even.

Kevin: Exactly.

Dr. Biology: We've been talking about colors in general, but you have one particular color that you have a real interest in. In fact, "ASU Research" magazine had an article on you not long ago, called "Being Red." And that makes sense, because that's a real particular color that you have an interest in. Can you talk a little bit about that?

Kevin: At one level, red is really interesting in nature, because it's a really rare color. If you look across the world, in the variety of environments or habitats that you can think of off the top of your head--whether it be an open, green grassland, or a forested, green landscape, a blue to dark oceanic background--red stands out in almost every environment out there.

And so if an animal, or even a plant, can become red, they can certainly, again, stick out, and allow themselves to be know to their partners, to be known to the members of their species, and to facilitate communication.

This phenomenon of red being very bold and informative transcends into humans, where, in various sports teams and athletic games, we find that individuals that are wearing red often tend to be the more successful winners in these competitions; as if they're somehow advertising their ability to be fearless and fearsome and overcome their competitors, in these Olympic and other challenges.

So yeah, in birds, redder is better; redder stands out. And this really tends to span all sorts of organisms.

Dr. Biology: So as far as the sports figures, you're talking about like the Tiger Woods and the famous red shirt on the final day...

Kevin: That's right. That's right, the Sunday red. He comes fully adorned.

Dr. Biology: How about other less colorful birds? Do they have a story to tell, even if they don't match the bright-colored parrots that we've been talking about?

Kevin: Yeah. One group of birds that you might think about are the house sparrows that you see, often, flittering around your bushes or, again, eating seed from your feeders. The males have a dark black badge, a patch of throat feathers right on the bib, which is lacking in the females. And in this case, we wouldn't necessarily agree that this is a strikingly colored, ornamental species, right?

But we would say that there's a difference between the male and the female, and that may play some role in mating or in communication. And so, in theory, we could predict that the individuals with the blackest or the biggest badges might actually be the best themselves; and in fact, we do see this.

Those individuals in the house sparrow species where males that have big black badges are actually the males that are the most aggressive, they're the most dominant, and they experience the highest forms of success, in competitions and in mating, than those that don't. So there can be all sorts of colors. They don't have to be incredibly brilliant. And yet, animals are using them, in really particular ways.

Dr. Biology: When I was reading through the article about you, it mentioned that you've never really had any parrots in your laboratory.

Kevin: That's right. All the research we've done on parrots has been from feathers that have been sent to us by various zoos, pet parrot owners, museums and other parts of the world where people are studying parrots, so up until within the last year or so I never had physically even handled a parrot.

It was only through a connection with a local pet store during an interview we did on campus where they actually brought to us a brilliant big red scarlet macaw that actually sat on my shoulder during an interview that's actually available on the ASU website.

Dr. Biology: Do you have a favorite parrot or coloration of parrot?

Kevin: Boy, I guess my favorite parrot right now is the budgerigar. Incidentally, the budgerigar, or the budgie is an Australian parakeet that's been domesticated and brought over in the pet trade, so you can head over to PetSmart and see these birds flying freely in the facilities of these pet stores.

It was about a month ago that I got a phone call in my office and someone said: "We've got a big parakeet down in the advising office here in the life sciences complex. Can you come take a look at it or take care of it?" And I said: "Why, I don't know how much I can do for it, but, yeah, I'll be happy to come down." I was expecting one of these big, peach-faced lovebirds which of course are a local parrot that's been released by some of the pet owners and has actually taken up residence. It almost looks like it belongs here in sort of tropical Phoenix.

The budgerigar was waiting for me in the office was a small, sort of bluish-gray parakeet, sitting on someone's finger. It didn't have an owner, it didn't have a home, and so now he lives with me and my family. At home here in Tempe, we've had him for just about a month, he's our proud new pet that my four, two and nine month old have just an absolute blast listening too and watching.

Dr. Biology: What's the name?

Kevin: The name is, frankly enough, Budgie, as my four-year old had intimately come to know it from the first time I told her it was a budgie.

Dr. Biology: Do they sing?

Kevin: They do. While they produce really intricate vocalizations, not necessarily the mating songs that we think of that happen during the breeding times. But they do produce melodious sorts of calls. And it's really neat, especially in the mornings we open the window or the door to get some nice fresh air in and it'll hear the local birds, namely the Verdins, the small, yellow backyard birds - they'll often nest in cacti - who would produce a specific call that the budgie hears and actually mimics and tries to call back and forth with.

So as soon as that Verdin in our backyard calls, it will call back. And it tries and tries to maintain that form of communication. And so it's got a little local friend.

Dr. Biology: That's very cool. Do you have a favorite color?

Kevin: Boy, my favorite color growing up has been blue. And it's been blue basically I've been a sports fan all my life. And one of my favorite teams was incidentally the Toronto Blue Jays. And so even before I got interested in science or in ornithology and color, I was interested in the color blue.

Dr. Biology: [laughs] Well, that brings me into three questions I would like to ask all my biologists. When did you first know you wanted to be a biologist?

Kevin: Well, I think it came probably in the early years as an undergraduate student. I went to a small school in upstate New York and then to St. Lawrence University; small school, about 2,000 students. And I entered the university, sort of interested broadly in the environment and in issues in conservation, took a class called "Conservation Biology" which was taught by an ornithologist.

And it was really then that I started to become fixated on the powers of science and the ability to use the scientific method to ask all sorts of questions about the world around us. I was first able to start to ask some of those questions. Luckily enough, in that course where we actually traveled to the tropical rain forest in Costa Rica to actually become immersed in issues in conservation. And yet tagging along with my ornithologist professor, he couldn't and then I couldn't help but be awestruck by the sheer brilliance of all of the birds and their colors in the tropics. So from that moment on I've been hooked.

Dr. Biology: You've been hooked. Okay man, I'm going to unhook you. I'm going to take all of that away from you because I want to know who you'd be if you could not be a scientist or a biologist.

Kevin: I partly answered that question I think. Given my athletics background, I would probably be a coach. I've had a little bit of background experience in coaching baseball for example, which I played in a small division during school as an undergraduate. And I really find tremendous challenges athletically. In many ways, it doesn't have its analogous situation to science. But it's a nice outlet, it's a nice sort of mechanism by which I can get away and experience a whole new challenge in life. So I'd probably be associated with athletics.

Dr. Biology: As a coach.

Kevin: Yeah.

Dr. Biology: What position did you play?

Kevin: I was an infielder, so I bounced around between shortstop second base and third base.

Dr. Biology: What advice would you have for young scientists?

Kevin: Boy, as a young scientist myself, I guess I would call it, in the back of my undergraduate years, I've simply come to appreciate how many ways that science plays a role in our lives. It starts in the morning when you wake up and decide what to eat for breakfast, or what to wear. You undergo parts of a scientific method, coming up with hypotheses or observations about what you would like or like to wear, you then test those maybe by trying them on or looking through the cabinet at particular foods. Then follow it through by testing your hypotheses and seeing how well, you know, the clothes look and deciding on one, you know, potentially feeding back and revisiting it maybe the next morning if you want to wear something different or eat something different.

So these are obviously minor examples of the way science can influence lives, but it really goes all the way up to all the amazing things that people can learn about themselves, about the world and just become so much more informed about how and why things work on the planet. That I would encourage all young students to just really become immersed in what science can do for them and for humans on earth and for all other species on earth.

Dr. Biology: Could be even for picking a color of the shirt you're going to wear that morning.

Kevin: There you go - perfect link back to the colors.

Dr. Biology: Well, Kevin McGraw, thank you for visiting with us today.

Kevin: Thank you very much for having me.

Dr. Biology: You've been listening to Ask-a-Biologist and my guest has been Professor Kevin McGraw from the ASU School of Life Sciences. If you'd like to learn a little bit more about color and color vision you can visit the Ask-a-Biologist website and look up the article called "Seeing Color". If you'd like to know a little bit more about Dr. McGraw, you can come to the podcast content link on our website. We will have some links to articles about him and also some books he has written. By the way, there are two books that you've written recently, right?

Kevin: That's right. Called "Bird Coloration". Full of approaches on methods and technical questions about how colors are produced as well as why we see such a diversity of color out there in the avian world.

Dr. Biology: Can you get it at Amazon?

Kevin: You can buy it at Amazon.com.

Dr. Biology: Very good. This has been Ask-a-Biologist, the podcast, and you've been here on the campus of Arizona State University, even though our program is not broadcast live, you can still send us your questions about biology, using the companion website. The address is askabiologist.asu.edu or you can just Google the word Ask a Biologist. I'm Dr. Biology