This is a transcript of The Conversation Weekly podcast episode 'Discovery: Reindeer's fascinating color-changing eyes', published on December 21, 2022.

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Dan Merino: Hello, I am Dan Merino. Welcome to the Conversation Weekly. Today we've got another episode from our discovery series. This is where we talk to one researcher about something cool they've been working on that we think more people should know about.

It's the holiday season, a time when the North Pole is top of mind for many people around the world. And for today's episode, we wanted to share with you a fascinating recent discovery about reindeer — specifically about how their eyes have adapted to see in the unique light conditions of the Arctic. I sat down with Glen Jeffrey, a professor of neuroscience at the Institute of Ophthalmology at University College London in the UK. He studies vision in animals and how their vision adapts to their environments.

A few years ago, some researchers in the Arctic Biology Department at the University of Tromsø in Norway, got in touch with Glen and asked them to take a look at some reindeer eyes that they thought were rather unusual.

Glen Jeffery: They sent me various pots of eyes from a slaughterhouse up there. And they had a big label on one, it said, "Summer," and a big label on another one, and it said, "Winter." And I thought it was a bit cheeky of them, so they got left on the shelf for quite a while.

Dan Merino: So, hold on. They sent you pots of eyes, of reindeer eyes?! What do you mean they sent you pots of reindeer eyes? I didn't think you could send that through the mail.

Glen Jeffery: Oh, yeah, you can send anything, I suppose, if you want. They were eyes that had been taken when animals were slaughtered for other reasons. So you've gotta remember that up in the arctic, reindeer are basically cows. They are used as a source of meat, and because they wanted to really provoke this area of research, they sent them down to me and said, well, maybe you could have a look. And I thought, that's crazy. You're sending me eyes, fixed eyes. What am I supposed to be looking for? I had no idea.

Dan Merino: Eventually Glen's curiosity or maybe just a bit of boredom took over. And the eyes came off the shelf. At first when he opened one of the pots, he didn't really see what the big deal was.

Glen Jeffery: So I opened up the summer ones first, and I thought, I'm wasting my time here. And so then we opened up the other eyes and that was when there was a shock. Because the winter eyes were blue. I'd never seen anything like that in my life before.

Dan Merino: Okay, so to understand why Glen was so intrigued when he pulled these blue eyes out of the pot, you have to understand a bit about non-human mammalian eyes.

Glen Jeffery: Most animals — and it doesn't include us — most animals have got a mirror behind their eye. And you see this occasionally when you're driving along and you catch an animal in your headlights. You'll see there's a shine from the eye, and it's a mirror. It's a mirror that lots of animals have got. It's called the tapetum lucidum, and it's there because in evolution, mammals were very nocturnal. So what they do is, the light comes through the retina where some of the photons are captured, but then what it does is, this mirror bounces the light back out through the retina for a second pass. Now that doubles your chance of seeing something. Now when you're a night animal or you've evolved in darkness for a hundred million years, that's really important. So the tapetum lucidum in mammals is a standard golden color. So if you open up a cat's eye, you'll see a golden reflection behind the retina.

Dan Merino: I mean you say every, every tapetum is gold. Do you mean like every tapetum is gold?

Glen Jeffery: There's little variations, but I've never seen a tapetum that wasn't gold.

Dan Merino: So when Glen opened up these reindeer eyes and saw a blue tapetum, something he had never seen before, something he'd never heard about, he wanted to make sure he wasn't, well, seeing things.

Glen Jeffery: I went next door to the chap who had inspired me to do comparative vision, and I said, Hey, Jim, come and have a look at this. And he looked at it and he said, uh, they've done something wrong. They, they put the eyes in something they shouldn't have put it in. But no, it was real. And we're not talking about minor color change. We're talking about a very obvious color change.

Dan Merino: So Glen and some colleagues packed up their gear and traveled to Tromsø, which is located far north in the Arctic Circle in Norway.

Glen Jeffery: And the interesting thing was that winter in the Arctic is not dark particularly. It is just saturated, deep, deep blue light. So as the sun is below the horizon and the light has a very, very long pathway through the atmosphere, the red light gets filtered out, and all you're left with is very, very dim blue. It's very, very deep blue. So we are looking around, and we're saying to ourselves, this animal is matching its visual system to its environment. I'd never seen that before. Okay. Never seen that before!

Dan Merino: Does the color of the tapetum kind of match the wavelength of blue light? Like, is the tapetum like better at reflecting this wavelength of light? Is that what we think is happening here?

Glen Jeffery: Exactly. Exactly. So again, if you are in a dark environment, you want to capture every photon that you can, and you want to bounce it back. And then you want, if you possibly can, to tune the ones that are in your visual environment. It's a blue environment, you want to maximize the blue. You don't wanna be turning the amplifier up on the red or the green. That world's blue, that's what you want to see.

Dan Merino: What advantages do you think reindeer get from this adaptation? Like certainly, yeah, seeing is good, but why don't other animals have this?

Glen Jeffery: The Arctic world is a world where there aren't many colors. Now, the reindeer does something else which is quite unique. It not only magnifies its blue, what it sees, but it also sees into the UV. So our vision stops at around 400 nanometers. Now, going below that, we can't see. We can't see into the UV. The reindeer can, so it's magnifying, so its blue, it's magnifying its UV.

Now, the great story for the reindeer then is that if it sees a wolf — now a wolf will be white in winter — what will happen is, the wolf's fur will absorb certain wavelengths, and instead of it appearing in the UV, instead of it appearing white, it will appear dark. So in the UV deep blue, when the reindeer turns around and sees a wolf, what it sees is a white surface — the snow — and then the wolf breaks camouflage, because its fur is no good to it anymore. It appears dark. Now, unfortunately — well, fortunately, unfortunately — in Northern Norway, really there are no wolves there. But this is a mechanism which is still very important to the animal in North America, in Canada, in your caribou, which is the same animal. It's very important to the animal in Siberia, because there they are predated by wolves.

Dan Merino: Once they'd established that this color change gave the reindeer an advantage in winter, Glen and his colleagues wanted to figure out just how much of an advantage this was. To do this, they needed to perform an Electroretinogram, or ERG, on a reindeer and compare the eyes in the summer mode to eyes in the winter mode. An ERG is a test that measures the electrical activity of a retina in response to light. Of course, you can't just walk up to a wild reindeer and hope for it to sit still while you shine light in its eyes and measure its neural activity. So what they would do is purchase reindeer from the local Sammy people. These are an indigenous group that live in the far north of Norway, and who raised reindeer for food. Glen and his colleagues couldn't just do their experiments out in the wind and the snow, so they needed a lab fit for a reindeer.

Glen Jeffery: So we had to anesthetize our animals. Because winter animals overheat almost immediately, we had to pack the anesthetized animal in ice. So we've got a reindeer packed in ice, we've got a whole group of people in the room freezing with loads of layers of clothes on because it's so cold. And then we shone lights of different wavelengths into the animal's eye in different seasons, and it's very clear that blue light — the blue light in winter — gets a massive response from the winter eye in the reindeer. So we quantified the response from the eye to different wavelengths. And the retina in winter is uniquely sensitive in a way that it's not in the summer.

Dan Merino: Are there any other animals that change the color of their tapetum?

Glen Jeffery: No, never found one, but there again, there are very, very few mammals in the Arctic. Um, there's seals, there's polar bears, arctic fox, reindeer.

Dan Merino: So now that Glen and his colleagues had confirmed that reindeer eyes do, in fact, change in winter and had begun to measure just how effective this change was, they turned to the question of, how? The tapetum in most mammals, including reindeer, is made up of a collection of long collagen fibers. These are arranged in a way that kind of looks like a box of drinking straws. And if you were to look at the flat mirror surface of the tapetum, it'd be like looking at the top of the straws into the holes. You see a bunch of holes and the straws extend behind them. This structure is called a photonic crystal.

Glen Jeffery: And what the animals do is they change the spacing of those collagen fibers between summer and winter. So if the fibers are very wide apart, as they would be say in a golden tapetum, now you start pushing them together and they move towards blue.

Dan Merino: So it's almost as if, like, the weave of a fabric is getting tighter and winter for a bad example?

Glen Jeffery: Exactly, exactly.

Dan Merino: Interesting. Why does a wider weave reflect gold light better, or kind of warmer lights better, where a tighter weave reflects cooler, kind of blue and UV light better? What's the kind of physics going on there?

Glen Jeffery: Well, the physics is all defined by something called Bragg's Law, and Bragg's Law just says that if you've got a series of aligned fibers, you know, very, very small micro fibers, and you change the spacing, so you dial through the visible spectrum from going from blue to deep red.

Dan Merino: Reindeers' tapetum is gold or blue for the same reason that bird feathers often have an iridescent sheen in coloration that can be really surprising. Think of a peacock or a hummingbird, or even a crow or a raven, if you get close enough, have these beautiful purple and blue colors. This is called structural coloration. And the reason you see a certain color is because when light enters a tapetum or a feather, certain bits of it get stuck bouncing around, and what comes back out is the color you see. So by changing the structure of the feather or the tapetum, you change the color.

Okay, so how the heck do they change the leave of the back of their eye? That seems a little crazy.

Glen Jeffery: This one took about four years to work out, cuz we're taking eyes and we're doing gene analysis, and then I just happen to notice something which I'd never noticed before, which is, when you wake up in the morning, the pressure in your eye is greater than it is when you go to bed at night. So, as you close your eyes, or if you are in the dark, your iris expands, your pupil gets bigger. Now, as it does that, it blocks, it's called the trabecular meshwork, which is a mouthful, but what it does is it blocks the main drainage pathway in the front of the eye. So if we just imagine, you are blocking a drain. As you block a drain, the pressure will build up. As the pressure builds up, it forces the fibers to come closer together as they squeeze out the fluid between the fibers. This is kind of the basic principle of a major eye disease: glaucoma. Because in glaucoma you actually find, in most of the cases, the trabecular meshwork, the drainage gets blocked, and the pressure of the eye goes up.

So, you know, it was a— we would say a road to Damascus moment, when we suddenly sat there and thought, we wasted all our time on this analysis of genes and all the rest. It was a simple mechanical process that was occurring. So the animal in winter goes into the darkness. It dilates its pupil, its iris folds back, and as it folds back, it blocks a drainage pathway, and the pressure in the eye just goes up and bumba dumba dum — the changes all go forward like that.

Dan Merino: Huh. So how fast does this happen? Is there a transition period where you kind of have an in-between color?

Glen Jeffery: There is a transition period over a period of about a month. But here's something really funny, I mean really unusual about it. So we ended up one day with a group of reindeer, and we are looking in their eyes and we're going, it's green. Oh my God. It's green! Well, you know, and then we're getting arguments, you know, some of the Norwegian guys are going, are you sure you guys know what you're doing? What's going on? We found that those reindeer, we normally used to go right out into, you know, the hinterlands or there's nothing there, and we'd buy reindeer and we'd bring them in to work on them.

Well, we had some reindeer that the University of Tromsø is on a hill overlooking Tromsø. In winter there's a small amount of light coming from the town. What happened was the animals couldn't make the full transition from gold to blue because they could see some, so the pupil wasn't really dilated properly. The drain was only partially blocked. So light pollution was having a major effect on the ability of the animal to change its eye seasonally and to adapt to a different light environment.

Dan Merino: So these reindeer that are living near Tromsø, do you think they are at some sort of disadvantage, or as long as there's enough light kind of nearby, their eyes are perfectly tuned for the Tromsø environment?

Glen Jeffery: No. So what we did was we, we grabbed some of those animals and we anesthetized them and we did the same experiment, we measured their retinal sensitivity. And their retinal sensitivity was nowhere near as good as it was in the animals that got a blue tapetum. So the animals were definitely at a very significant disadvantage, and that's really important when you think of places like Canada or even, you know, places like Northern Norway, when you're putting power lines through, when you're putting roads through, the animal will lose its visual sensitivity. And it's just not gonna lose it by looking at it; it's gonna lose it, and it's gonna have to live with that for a while.

Dan Merino: We talked about light pollution, noise pollution, all these things that are having serious effects on animals out in the wild. But because of the unique kind of way that this eye changes to adapt to winter, even just a little bit of light can really throw off this whole process, it sounds like.

Glen Jeffery: Yes, definitely. So when the animal with the green eye turns around to try and see the wolf, it can't see it anywhere near as well as the animal can who's got the blue eye and is attuned to its environment.

Dan Merino: Do we understand this mechanism fully or is there still more to be learned about here?

Glen Jeffery: No. You know, anyone who thinks they fully understand a mechanism of biology is making a big mistake.

Dan Merino: Spoken like a true scientist.

Glen Jeffery: Yeah, I think, I think we've got a handle on 70% of it; but these animals adapt in so many amazing ways in winter. They lose all their circadian rhythms in winter. No, I think I've got the biggest buy out of the lowest-hanging apple, but no, there's a lot more there to do.

Dan Merino: Glen, thank you so much for a fascinating conversation. Stay warm on your next trip up north, and please keep us informed. It's been a pleasure chatting with you.

Glen Jeffery: It's great to spread the word. Thanks for giving me the opportunity.

Dan Merino: A big thanks to Glen Jeffery and his colleague, Bob Fosbury, who we spoke to for this episode, and who wrote the original article on their research for the conversation. And thanks to our colleague Jenna Hutber at The Conversation in the UK, who also worked on that story. This Discovery episode from The Conversation Weekly was written and produced by Katie Flood with Gemma Ware and me, Dan Merino. Sound design is by Eloise Stevens, and our theme music is by Neeta Sarl. Our global executive editor is Steven Khan, and Alice Mason does our social media. You can find us on Twitter at tc_audio, Instagram @theconversation.com or email us: podcast@theconversation.com. And don't forget to sign up for our free newsletter. It's a good one. There's a link in the show notes. If you like what you hear, show us your support for the podcast and The Conversation, go to donate.theconversation.com. And of course, happy holidays and thanks for listening. We'll see you next year.