ROSLYN: You're listening to Brains On, where we're serious about being curious.

**VOICE:** Brains On is supported in part by a grant from the National Science Foundation.

[THEME MUSIC]

**MOLLY BLOOM:** In today's episode, we're getting into all about how animals can see the world around them.

[MUSIC SLOWS DOWN AND EVERYTHING POWERS OFF]

That is the third time we've lost power this week. What is going on? Well, our switch for the backup generators is somewhere in here.

**ROSLYN:** Do you think the experimental colony of blue iguanas is napping on the rooftop solar panels again?

**MOLLY BLOOM:** Maybe. The iguanas do love the Brains On headquarters solar setup. It's also possible that Marc and Sanden are replacing the wind turbine blades.

**ROSLYN:** They did mention decorating the turbines with sea shells, so when they spun we'd hear the ocean.

**MOLLY BLOOM:** Hmm. Roslyn, do you see a label that says Genny anywhere?

**ROSLYN:** Not yet. Who's Genny?

**MOLLY BLOOM:** Sanden can only do maintenance work if the thing he's working on has a name and a plant nearby. The generator is named Genny, and there's a potted queen of the night cactus next to it.

**HAWKMOTH:** Did Hawkmoth hear someone say queen of the night cactus blossom?

**MOLLY BLOOM:** Who's that?

**HAWKMOTH:** Hawkmoth is here.

**ROSLYN:** Hi, Hawkmoth. Where did you come from?

**HAWKMOTH:** Hawkmoth is generally around. But Hawkmoth is here for queen of the night blossoms.

**MOLLY BLOOM:** Do insects always refer to themselves in third person?

**HAWKMOTH:** Not all of them, but not all of them are named Hawkmoth.

**INTERVIEWER 1:** Fair point.

**HAWK MOTH:** And ah. Here's that queen of the night. Good thing you have the lights off. This sweet and juicy delicacy only blooms at night. Mm.

[SLURPING]

**ROSLYN:** How did you find that cactus flower so fast?

**HAWKMOTH:** Hawkmoth is way better at seeing in the dark than you humans. Hawkmoth actually slows its brain down a little to take in more light when it's dark to help Hawkmoth see better. Nothing crazy, but a human wouldn't understand.

[SLURP]

**MOLLY BLOOM:** Oh, wow. Oh, and here's Genny's switch, too. Thanks for your help, Hawkmoth.

**HAWKMOTH:** Wait, wait, wait. Let me get one more sip before you turn those awful lights back on. Queen of the night blossoms and Hawkmoth are both very nocturnal.

**MOLLY BLOOM:** As nice as it is to meet you Hawkmoth, we do have to get back to taping the show. So let us know when you've had your fill, OK?

**HAWKMOTH:** OK, Hawkmoth is satisfied, carry on.

[SWITCH]

[POWER UP]

[THEME MUSIC]

**MOLLY BLOOM:** You're listening to Brains On from American Public Media. I'm Molly Bloom, and I'm here today with Roslyn from Duluth, Minnesota. Hi, Roslyn.

**ROSLYN:** Hi.

**MOLLY BLOOM:** Today, we're talking about how animals see the world, because you sent in a great question about this. Do you remember the question that you sent in?

**ROSLYN:** Do insects see things slower than we do or faster?

**MOLLY BLOOM:** And what made you curious about that?

**ROSLYN:** Well, I was actually watching a film where they had people who were walking slower, and then there were tiny people who were walking faster, and it was, I don't know, it got me interested.

**MOLLY BLOOM:** So you were thinking maybe if you are a tiny insect do you see people slower just like the tiny humans in that movie?

**ROSLYN:** Yes.

**MOLLY BLOOM:** That inspired us to look into the wild world of animal vision. And you're not the only one who wondered about how animals see the world.

**MAYA:** Hi Brains On. I'm Maya, and I was wondering, why do we see different colors than animals?

**FINJA:** My name is Finja, and my question is, do animals see the same rainbow we do? And if not, how is it different?

**SILAS:** My name is Silas. I'm from Fairbanks, Alaska, and my question is, how do some animals see heat?

**ZOYA:** Hi, my name is Zoya.

**QUINN:** Hi, my name is Quinn.

**ZOYA:** Our question is, why do we see colors that some animals can't see?

**HARRIET:** Hi, my name is Harriet, and I'm from Ohio. My question is, how can eagles and other birds see from so far away?

**MOLLY BLOOM:** Before we get into animal eyeballs, let's talk a little bit about how we see the world.

**ROSLYN:** Our brains build a picture of the world from the light that our eyes take in.

**MOLLY BLOOM:** Two kinds of cells at the back of your eye tell your brain what light is coming in. One is called a rod and the other is called a cone.

**ROSLYN:** Rods are great for seeing in low light and cones tell your brain about color.

**MOLLY BLOOM:** Rod and cone-- they sound like a TV sitcom duo.

[CHEESY MUSIC]

**VOICE:** Rod and cone. Friends in your eyeholes.

(SINGING) They're seeing the world. They're sensing the light. Cone's good at color. And rod is good for the light. Yeah.

**ROD:** We're friends, right, pal?

**CONE:** You got that right, buddy. High five.

**ROSLYN:** I'd watch that with my rods and cones.

**MOLLY BLOOM:** Same. So speaking of cones, most people have three kinds-- ones that sense blue, ones that sense green, and ones that sense red. And those cones combine to help us see a lot of different colors.

**ROSLYN:** By the way, people who are colorblind might have fewer cones, or their cones might not work as well, which makes it harder for them to tell colors apart. But even people with the usual number of cones can't see all the light in the world.

**MOLLY BLOOM:** That's because light can travel in a wide range of energy levels. Our eyes can only detect a tiny fraction of it, just a very specific range.

**ROSLYN:** It's similar to hearing, how you can hear this tone?

[TONE]

But as it gets higher and higher in pitch, it gets harder and harder to hear until it's gone.

**MOLLY BLOOM:** The tone is still there. We just can't hear it anymore. Our ears aren't equipped. But other animals might be able to hear it.

[DOG BARKS]

**ROSLYN:** Like dogs. They have good ears, cute fluffy good ears.

[DOG BARKS]

**MOLLY BLOOM:** It's similar with light. All the light we see is only part of the light out there. We call that visible light. But there's light that's much lower in energy, like radio waves and microwaves.

**ROSLYN:** Which we can't see.

**MOLLY BLOOM:** Then there's light that's much higher in energy, like ultraviolet waves or gamma waves.

**ROSLYN:** Which we also can't see.

**MOLLY BLOOM:** We call this entire range of light the electromagnetic spectrum. It's so cool and important, we wrote a song to help you remember it. The waves go in order from lowest energy to highest energy. Hit it singers.

[MUSIC PLAYING]

**SINGERS:** (SINGING) Radio, microwave, infrared, visible, ultraviolet, X-ray, gamma. Yeah, here we go. Space between waves gets shorter and shorter. Electromagnetic spectrum that's the order.

Radio, microwave, infrared, visible, ultraviolet, X-ray, gamma. Radio, microwave, infrared, visible, ultraviolet, X-ray, gamma. It's the electromagnetic spectrum, the electromagnetic spectrum. These are the facts we checked them. The electromagnetic spectrum.

**MOLLY BLOOM:** So lovely.

**ROSLYN:** And informative.

**MOLLY BLOOM:** Exactly. Now, we can't see things outside the visible spectrum, but some animals can. And they have some feelings about it. We checked out an animal vision support group to hear more about that.

[MURMURY TALKING AND SHUFFLING]

**MAL THE MANTIS:** Ahem. Welcome to the Eyes Wider Open support group. Here, we can all share what it's like to see the world through our eyes. If we haven't, ahem, seen you here before, welcome.

[GROANS]

OK, OK, some of you are tired of my little joke. Thank you for that feedback. I want to kick off with intros. So I'll start.

I'm Mal. I'm a mantis shrimp. I can see ultraviolet light, and I have a bunch of different color sensing cells, but scientists don't think I'm great at telling colors apart. And I'm still processing that.

**CECILY SNAKE:** I'm Cecily. I'm a pit viper, and I'm amazing. I see a heat map of whatever I'm looking at.

**CALEB CARIBOU:** I'm Caleb. I'm a caribou, and I have really big eyeballs that can see ultraviolet light, like Mel. That makes my world much brighter.

[PANTS]

**LANDRY LAB:** Hi, I'm Landry.

[PANTS]

I'm a yellow lab. My eyes have two kinds of cone cells. So I can tell blue and yellowish stuff apart pretty well. But the other colors are a bit mushy.

**BO BLUEBOTTLE:** And I'm Bo. I'm a bluebottle butterfly. I have exquisite color vision. Like Caleb and Mal, I also see UV.

**MAL THE MANTIS:** Wow. Great. Thank you all so much. So who would like to start today?

**CECILY SNAKE:** I'll start. Thank you, Cecily. So pit vipers have these two pit organs on our faces. See, they look like second nostrils but bigger. They help me see in a different way.

My pit organs sense heat. My eyes see what's around me. And my brain puts the two together.

**MAL THE MANTIS:** Fascinating. How do you feel about that?

**CECILY SNAKE:** Well, for one thing, I'm tired of getting here and looking at the coffee and seeing that it's cold. The coffee here is never hot, and it's so uncivilized that you all just keep eating and drinking lukewarm stuff. If you had any decent snacks, I'd spot them right away. Would it kill you to put a warm mouse on the snack table every once in a while?

**MAL THE MANTIS:** Hmm. OK, good note. Thank you for sharing, Cecily. I'm going to pass your snack request on. Who would like to share next?

**CALEB CARIBOU:** I can. I'm just feeling a little misunderstood. No offense Mal and Bo, but everyone gets why bugs and shrimps use their UV vision to find friends and food. But they just don't get me.

**MAL THE MANTIS:** Wow, Caleb. That sounds really hard. Can you say more?

**CALEB CARIBOU:** Well, seeing UV light helps me tell important things apart, too. Snow versus lichen versus a hungry wolf, for instance. It's extra helpful to let more light into my eyes in the dark arctic winter, when my world is a deep, deep blue. But also, UV vision highlights urine. So I knew not to sit in the chair that Landry marked, for instance.

[PANTS]

**LANDRY LAB:** Couldn't help myself. Apologies.

**MAL THE MANTIS:** So expressive, Landry. Thank you. And thanks for sharing, Caleb. Bo, you haven't shared for a while. Tell me how you're feeling today.

**MOLLY BLOOM:** OK, let's give our eyes a rest and instead activate our ears. It's time for the--

**WHISPER:** Mystery sound.

**MOLLY BLOOM:** Here it is.

[PLAYS SOUND]

So what is your guess?

**ROSLYN:** I think it's some sort of seal, maybe a seagull?

**MOLLY BLOOM:** Hmm, a seal or a seagull? Excellent guess. Well, we're going to hear it again and be back with the answer in just a little bit.

[MUSIC PLAYING]

We love hearing from you, whether you're drawing pictures of Hawkmoth, finding super tricky mystery sounds to stump us, or sending us questions. They always make our day. You can send all of that kind of stuff to us at brainson.org/contact. That's where we got this question.

**SUBJECT 1:** My question is how and why does corn pop into popcorn?

**MOLLY BLOOM:** You can find an answer to that on our*Moment of Um* podcast. It's a dose of facts and fun every weekday. You can find it wherever you listen to this show. Just search for *Moment of Um.* And at the end of the show today, we'll read the latest list of listeners to be added to the Brain's Honor roll. So stay tuned.

[MUSIC PLAYING]

**ROSLYN:** You're listening to Brains On from American Public Media. I'm Roslyn.

**MOLLY BLOOM:** And I'm Molly. OK, before we get back to eyes, we need to go back to our ears first. Let's hear the mystery sound one more time.

[PLAYS SOUND]

OK, so before, you said a seal, maybe a seagull. Do you have any new guesses?

**ROSLYN:** I think that I'll stay where, I guess.

**MOLLY BLOOM:** Some kind of animal?

**ROSLYN:** Some kind of animal that's fairly obnoxious.

[LAUGHS]

**MOLLY BLOOM:** Well, here is the answer.

**TIFFANY PLOEHN:** So the sound you just heard is the call of a bald eagle. My name is Tiffany Ploehn. I'm the avian care manager of the National Eagle Center.

**MOLLY BLOOM:** Did you know that? Have you heard an eagle before.

**ROSLYN:** I have. Actually, at our cabin I hear them all the time.

**MOLLY BLOOM:** It's hard when you hear these sounds out of context. It's like--

**ROSLYN:** Yeah.

**MOLLY BLOOM:** You could hear something super familiar to you, and when you hear it out of context, it's super hard. But that's really cool that you get to hear bald eagles.

**ROSLYN:** Yeah.

**MOLLY BLOOM:** I've never heard a bald eagle before. That's not what I would imagine it sounds like.

**ROSLYN:** They're loud.

**MOLLY BLOOM:** It's very loud. Are they obnoxious like you thought?

**ROSLYN:** Sometimes. It's cool when you hear them though.

[EAGLE SOUND]

**MOLLY BLOOM:** The National Eagle Center is in Wabasha, Minnesota. They educate people about these winged wonders. And if you are surprised that was the sound of a bald eagle, you're not alone. Tiffany says most people think a bald eagle sounds like this.

[HAWK SCREECH]

But that's not a bald eagle.

**TIFFANY PLOEHN:** When you see eagles and movies and commercials and you see them flying around, you always hear that really loud majestic car sound, and that's actually a red tailed hawk sound, and they dub over an eagle sound with it.

**MOLLY BLOOM:** Cool trivia, right? But back to eagles, they have some of the sharpest vision in animal land, in part, because their eyes are super special.

[MUSIC PLAYING]

**TIFFANY PLOEHN:** Eagles eyes are pretty unique in the fact that they have actually two focal points in their eyes or fovea. And so they have kind of binocular vision like we do, where they can see straight forward. But then they have a monocular vision that goes off about 45 degrees in each eye.

**MOLLY BLOOM:** So imagine being able to see very clearly what's ahead of you. But also, what's lurking at the side of your vision, you can see that clearly too.

**TIFFANY PLOEHN:** And by going back and forth between them, they can get this really distinct kind of 3D vision. And so that's how they have such fantastic depth perception.

[EAGLE CALLS]

**MOLLY BLOOM:** This helps them hunt tiny critters like rabbits and rats. Tiffany says eagles also have extremely large eyes compared to their head size, and they can see ultraviolet light. Overall, their vision is 4 to 5 times better than ours.

**TIFFANY PLOEHN:** For instance, we have some fun comparisons, like, an eagle, if they were sitting on top of a 10 story building, could look down and actually see a carpenter ant and walking along the sidewalk. Or they can see a rabbit, if it was running, if it was about 24 inches long, they could see that rabbit running along a bluff about 3 miles away.

**MOLLY BLOOM:** Not bad eagles. Not bad. Now let's answer the question that inspired this whole episode.

**ROSLYN:** Is it true that small bugs and insects see humans moving slower than they are? Or do we see ourselves moving faster than we think?

**MOLLY BLOOM:** To find the answer, Roslyn and I visited a lab at the University of Minnesota.

**PALOMA GONZALEZ BELLIDO:** My name is Paloma Gonzalez Bellido. I am an assistant professor at the ecology, evolution, and behavior department at the University of Minnesota, and I study how insects see the world and how they catch their prey.

**ROSLYN:** Paloma and her team invited us to their lab and answered many of our questions about how insects see the world.

**MOLLY BLOOM:** Researchers Kate Feller and Sergio Rossoni started by showing us where they raise the insects they study. It's warm.

**KATE FELLER:** How. It's why we're here. So this is the room where we rear all of the insects. You'll notice that it's pretty warm in here, and it's very high humidity. And that's essentially to keep them really happy because otherwise if it's too dry like in the winter we really struggled with getting them to not dehydrate.

**MOLLY BLOOM:** They raise dragonflies and killer flies.

**KATE FELLER:** We're really interested in the fact that they hunt and kill stuff. And they do it while they're flying.

**MOLLY BLOOM:** And so in studying the way these insects catch other insects to eat, they need to study the way their brains work, particularly the way they see.

**PALOMA GONZALEZ BELLIDO:** They definitely see much faster than we do. Basically, they have photoreceptors that work really, really quickly. And photoreceptors are the cells in your eye that transmit light into electrical energy. Those are the ones that make us see. And they have a very nice and tricky difference to the way that our eyes work. And that's why they can see so fast.

**SERGIO ROSSONI:** So you might have seen films of giants that move really slowly compared to us. And that's because any animal that is bigger is going to require a lot more muscle force, that is going to require a lot more time to be able to develop. So the smaller you are, the faster you can move. But of course, that's going to-- if you see very slowly and you move really fast, that's not going to be very efficient. So vision is going to match up and try to be as fast as your movements are.

We've got slow vision compared to most other animals because we don't require that fast vision because we can't move that fast anyway. So that would be a waste of energy.

**KATE FELLER:** Yeah, your question actually sparked very interesting philosophical debate.

[LAUGHTER]

Like, it's a bit of a misrepresentation to say-- at least I think-- to say that insects have slow motion vision or that they see the world in slow motion because I can't ask them how they perceive time and space. And we can never ask them because we can't talk to them directly.

However, they do have high speed vision like a high speed camera. So the slow motion camera on your phone is actually a higher speed camera than your regular camera. So it's just capturing frames at a faster rate than our visual system is able to.

**MOLLY BLOOM:** How do you study their brains? Because you can't-- or can you put--

**KATE FELLER:** You can.

**MOLLY BLOOM:** --little electrodes on them?

**KATE FELLER:** Yeah, you put little electrodes on them, and then you measure the electricity.

**SERGIO ROSSONI:** Very patiently and with a microscope.

**KATE FELLER:** Yeah, very delicate and very patient.

**MOLLY BLOOM:** How do you get them to stay still?

**KATE FELLER:** Actually cold is really good for-- it's a good anesthesia.

**ROSLYN:** And how do these discoveries help modern day technology, would you say?

**KATE FELLER:** Well, I mean that's like a little flying high speed camera that's able to grab stuff out of the air. I can think of a lot of applications for that. We're the modern day explorers that figure out what's going on in the natural world, and then people who do more applied work building stuff and inventing things can take the principles that we've figured out and then implement them in their own designs.

[THEME MUSIC]

**ROSLYN:** There's a whole range of life. It's called the electromagnetic spectrum.

**MOLLY BLOOM:** Humans can only see a portion of it. We call that part visible light.

**ROSLYN:** But some animals can see more kinds of light than we can, like infrared light or ultraviolet.

**MOLLY BLOOM:** Eagles have two focal points in their eyes which gives them extra powerful depth of vision.

**ROSLYN:** And insects do indeed see things differently than we do.

**HAWKMOTH:** And Hawkmoth can see better in the dark because Hawkmoth can slow down Hawkmoth's brain. Yay Hawkmoth.

**MOLLY BLOOM:** That's it for this episode of Brains On.

**ROSLYN:** Brains On is produced by Marc Sanchez, Sanden Totten, and Molly Bloom.

**MOLLY BLOOM:** Our fellow Menaka Wilhelm sees all. We had production help from Kristina Lopez and Jackie Kim. We had engineering help from Veronica Rodriguez. Special thanks to Becky Hartley, Helen Bond Plyler, The Dino Birds, Glenn Jeffrey, Ricky Patel, Brenna Everson, Peter Ecklund, Misha Euceph, James Kim, and Arwen Nicks.

**ROSLYN:** Brains On is a nonprofit public media podcast. Your support helps us keep making new episodes.

**MOLLY BLOOM:** Head to brainson.org/donatetogive. And while you're there, you can see our cool thank you gifts. Now, it's time for the latest group of listeners to join the Brain's Honor Roll. These are the people who send us mystery sounds, pictures, drawings, and questions to help fuel the show.

[HONOR ROLL]

**ROSLYN:** We'll be back soon with more answers to your questions.

**MOLLY BLOOM:** Thanks for listening.