

MOLLY BLOOM: You are listening to Brains On from American Public Media. We're serious about being curious. I'm Molly Bloom.
OK, it's a little dark in here. I'm having trouble reading what I've written here. Hold on.

[LIGHT SWITCH CLICKS]

Whoa. Have you noticed it always takes a little while for your eyes to adjust from dark to light and vice versa?
Well, we get a lot of questions about eyes and vision, like this one about color from Becca.

BECCA: How do we know if we all see the same colors, and is there a way you could test people's perceptions of colors?

MOLLY BLOOM: Think about it for a second. You say, hey, Molly, pass me the blue crayon, and I pass you the blue crayon. But what if the color that you call blue and the color that I call blue don't actually look the same at all? Like, what if the color that I call blue, the color of the sky or a blue jay or a Grover from *Sesame Street*--

Hello, there.

What if my eyes see that as the same color you call orange? Like, if you could see through my eyes, the sky would be orange, a blue jay is orange, Grover is orange, but since that's what everyone calls blue, I just think orange is blue.

[BOOM]

When our brains see color, we're really just seeing visible light. It's part of the electromagnetic spectrum.

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

We talked all about it in our episode about X-rays. Check it out if you haven't heard it yet. So within that range of light, most of it is invisible to our eyes. But there is a range of visible light that we can see. It goes from red to violet. Specifically red, orange, yellow, green, blue, violet, and all the shades in between. Each different color that we can see has a different wavelength. Violet has the shortest.

[HIGH-PITCHED WARBLE]

And red has the longest.

[LOW-PITCHED WARBLE]

You might be saying, wait, light has waves? Yes, it does. Light is just energy, and energy travels in waves. The size of a wave depends on the amount of energy moving through. Violet has the most energy, and red has the least.

[LOW-PITCHED WARBLE]

So we know the light wave reflected off the blue crayon is the same length no matter who is looking at it. So the question is all about how our brains process that information. Do we all visually process these wavelengths of light in the same way? Do we see the same colors?

Before we get to that very interesting question, it's important to understand how we process light. We're able to do it thanks to some special cells in the back of our eyes called rods and cones. They sit in an area called the retina. Let's go ringside for more.

[MUSIC PLAYING]

INTERVIEWER: Tonight, the body brawl match up you've all been waiting for. Which cell in the retina is the most important-- the rod cells or the cone cells? Both help you see, but only one will win tonight. In this corner, Rodney Rod.

RODNEY ROD: That's right. I'm Rodney. I'm a rod. Hoo-ha!

INTERVIEWER: And in this corner, representing cone cells in the eye, it's The Cone Sisters.

SUBJECT 1: Cone Sister roll call.

SUBJECT 2: Red.

SUBJECT 3: Blue.

SUBJECT 1: And green. We help you see colors.

INTERVIEWER: Triple trouble.

[BELL RINGS]

The Cone Sisters are photoreceptors. "Photo" meaning related to light, and "receptor," like something that receives signals.

SUBJECT 1: Yeah, we receive light waves and turn them into signals to help your brain see.

RODNEY ROD: Hey, I do that too.

SUBJECT 1: Welcome to the club.

SUBJECT 2: Yawn.

SUBJECT 3: Tell me something I don't know.

RODNEY ROD: OK, well, I'm also a nerve cell.

SUBJECT 2: You are?

SUBJECT 3: Really? I didn't know that.

SUBJECT 1: Ladies, we are nerve cells too.

SUBJECT 2: Oh, yeah. Right.

SUBJECT 3: Right.

INTERVIEWER: Enough chit chat. I'm trying to stoke the heat of competition here.

RODNEY ROD: Oh, right. Grr.

SUBJECT 1: You come for the cones, and you'll get burned.

INTERVIEWER: Cones help the brain see color.

SUBJECT 2: Yeah, and we help you see fine details. Rods don't.

RODNEY ROD: Oh, yeah? You may have fancy colors and highfalutin detailed vision, but without me, forget being able to see in the dark. I help brains see in low light.

SUBJECT 1: Yeah, but we're faster at processing light.

RODNEY ROD: I always say, slow and steady wins the race.

INTERVIEWER: Oh, wait. So that's why it takes so long for my eyes to adjust when the lights are turned off or when I go from outside to inside? It just takes you a while to do your job? You know, I wouldn't mind if you sped it up a little.

RODNEY ROD: Hey, now. Hey, now. I may be a little slower, but I'm super important if you want to see at night. And there are way more rods than cones. We've got you outnumbered.

SUBJECT 3: Who cares about numbers?

SUBJECT 1: We've got the color, the three of us.

SUBJECT 2: Red.

SUBJECT 3: Blue.

SUBJECT 1: And green. We work together to help you see all the colors of the rainbow.

SUBJECT 3: Can you rods do that?

RODNEY ROD: Well.

SUBJECT 1: That's what I thought.

INTERVIEWER: Enough talk. Let the match begin.

[BELL RINGS, CHEERING]

RODNEY ROD: Wait, we don't really want to fight.

SUBJECT 1: Yeah, we were just smack talking for funsies. We're friends.

SUBJECT 2: We actually work together in the back of the eye.

SUBJECT 3: We fill in gaps for each other. Human vision is so good because of our rod and cone teamwork.

RODNEY ROD: And we also have so much in common. Light hits us, and we send that signal to the brain so it can see the world around it.

INTERVIEWER: But-- oh. I guess this bout is over. Why does this always happen in my fights? Last week with the microbes in the intestines turn out to be friends, and now this. Well, next week's fight between the right hand and the left hand is bound to be better, right?

MOLLY BLOOM: Before we get back to Becca's visual mystery, we have an auditory one for you to tackle. It's time for the mystery sound.

[ELECTRONIC STINGER]

CREW: (WHISPERING) Mystery sound.

MOLLY BLOOM: Here it is.

[RUSTLING, CREAKING]

We'll be back with the answer right after this.

We're working on an episode all about elevators, and we have a question for you. What do you want the elevator of the future to be like? What feature would you like it to have? Where would you want it to be able to go or be able to do? Get creative and send your answer to hello@brainson.org. We'll include some of the answers in the show. You can also send your questions, drawings, mystery sounds, and high fives to that same email address.

Now's the time in the show when we thank the awesome kids who keep this show going with their energy and ideas. If you've written to us, we will get to you, we promise. But we're hearing from so many of you that there's a bit of a wait, so thank you for your patience.

[MUSIC PLAYING]

Ayla from Minneapolis, Calvin from Salem, Arkansas, Grace from Brush Prairie, Washington, Marcus and Clara from Fremont, California, Kate, Olivia, and Ruby, from Logan, Utah, David and Sophia from Sandy, Oregon, Brady from Brooklyn, Levi from Hawthorne, California, Carter from Dallas, Gideon and Isaiah from Coleman, Michigan, Jonah and Tatiana from Brisbane, Australia, Jolie and Ruby from El Dorado Hills, California, the third graders at North Fork Montessori,

Emma from Canberra, Australia, Max from Meadville, Pennsylvania, Sylvia from LA, Finn from Midvale, Utah, Gabriel and James from Seattle, Adam from Missoula, Montana, Samuel and Alexander from Mokena, Illinois, Logan and Willow from Waco, Texas, Elizabeth, Ryan, and Alex, from Championsgate, Florida, Megan from Galway, Ireland, Collin from Okinawa, Japan, Garrison and Clarinda from Manchester-by-the-Sea, Rhiannon and Foster from West Chester, Ohio, Alessia from Rochester, New York, and Elliot from Springfield, Virginia.

[MUSIC PLAYING]

MOLLY BLOOM: Ready to find out about that mystery sound? Let's hear it again. Here's your clue-- this is sound brought to you by the cold.

[RUSTLING, CREAKING]

Any guesses? Here's the answer.

HALEY: Hi. My name is Haley from Minnesota, and I'm seven years old. That was the sound of me and my family walking in the snow.

(SINGING) Buh-buh, buh-buh, buh-buh, buh-buh-buh-brains on.

MOLLY BLOOM: Now back to a question with a less clear answer. 10-year-old Becca from Baltimore wanted to know this.

BECCA: How do we know if we all see the same colors? And is there a way you could test people's perceptions of colors?

MOLLY BLOOM: It's a fascinating and complicated question, so we asked Becca to interview Dr. Robert Marc from the University of Utah to see if he can help us shed some light on the topic.

BECCA: I came up with this question because I was wondering what people are thinking and stuff. So then I started thinking about what colors they're seeing and then if we all see the same colors.

ROBERT MARC: This is a really hard question. So do we see the same colors? I'm going to be a perfect professor, and I'm going to say there are three answers. Answer A is yes, it all looks the same to us. And how do we know? And the answer to that is we can't find any evidence based on anatomy, genetics, behavior, electrical measurements in the nervous system, brain scans, mathematics.

We can't find any evidence that the world looks different to anyone. And we all agree, when we ask someone to pick out the blue crayon, everybody picks the right crayon, even people with some color vision deficiencies who are colorblind. So this is really important because it says that the way the nervous system is built is designed to make sure that we all see the same reality. That's pretty useful.

The second answer is a little harder. And that is yes, but we have learned that there are fine differences in the numbers of color cones that everybody has. So we still agree on what you'll call red, blue, yellow, or green, but you might disagree on what a complex color mixture looks like.

For example, my wife will see green tints in some fabrics that I call gray. We have different numbers of green cones in our eyes, so we will never agree, but the sky is still blue for us both, and we still agree on what we call green. We just have little differences in our color worlds.

BECCA: That's really cool.

ROBERT MARC: The third answer is we don't know. We actually don't see colors with our eyes. Our eyes pick up the colors and process them and send them to the brain. We don't even see the colors with our visual cortex. We now know that conscious perception happens somewhere in the forebrain, what we call the frontal and prefrontal cortex, and that's the part of the brain that is most complex.

So there's no way to know if everybody's processing areas actually work the same, but the evidence so far is that it does look the same. But does someone see the sky and it really looks red to them and they call it blue? I don't think we'll ever know the answer.

BECCA: Is there a way to enhance our color perception?

ROBERT MARC: Oh, wow. What a magnificent question. All of us think that just because we have senses, we know how to use them. But artists and painters spend a lot of time studying color and color mixture and looking at stuff. And people who work in the fashion industry have trained themselves to be much more sensitive to small color shifts than most people are. So you can actually work and train yourself to see colors better.

BECCA: So can you tell me more about the different colors that animals see? And also, do we see things that they don't?

ROBERT MARC: Actually, it pretty much works the other way around. Most animals, and when I say most animals, I mean lizards and birds and fishes, can see many more colors than we can. And their spectrum extends far into the ultraviolet and far further into the red than ours. And they have other color channels in the middle. They have different kinds of greens and different kinds of reds. They're much better at color vision than we are.

One difference, though, is our companion animals, dogs and cats. They have a green cone and a blue cone, but they're missing the red cone that we have. So they're kind of colorblind. They see a world of beautiful greens and sort of yellow tints. So they're not seeing the world in black and white, but it is a different kind of world. And it's the kind of world that a human with colorblindness would see.

BECCA: So are there any people who have extra rods and cones?

ROBERT MARC: So one of the things about the genetics of color vision that's really interesting is that our red and green cone genes are on the X chromosome. And females have two X chromosomes and males have only one. And so if you have damage to the DNA on one X chromosome in a male, you could be colorblind. And most cases of color blindness are in males.

BECCA: That's really interesting.

ROBERT MARC: But the same thing works in reverse because females have two X chromosomes. Sometimes there are mutations that do change the color of the cones a little bit. So there really appear to be a couple of different kinds of green cones, one that's more blue-green than the other. And there are some females that probably have a red cone, two kinds of green cones, and blue cones, and I would never want to get caught in a color matching test with that person. They would always win.

BECCA: I think that's really amazing.

MOLLY BLOOM: Thanks, Robert.

ROBERT MARC: Thank you. Bye, Becca.

BECCA: Bye.

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

[LISTING HONOR ROLL]

You can find more episodes of the show on our website, brainson.org, or wherever you usually listen. If you want to learn more about the electromagnetic spectrum, check out our episode all about X-rays. We'll be back soon with more answers to your questions. Thanks for listening.