Ask A Biologist Vol 068 (Guest Molly Cummings)

Cute Colorful Poison Dart Frogs and their Mimics

They might be colorful. They might be cute to some people. But don’t let that fool you. These bright colored frogs are poisonous. Dr. Biology talks with biologist Molly Cummings to learn about her work with some frogs that advertise to predators to stay away and other frogs that take advantage of this signal by copying the colors of their poisonous cousins.

Transcript

Dr. Biology: This is "Ask a Biologist," a program about the living world. I am Dr. Biology. For today's show I want to start out by us thinking about bright reds, screaming yellows, brilliant blues and gloriously intense greens.

If you've placed those colors in your mind, now think about some tiny tropical frogs that use these colors as warning signs. They're signals to other animals that they might not want to take a bite out of them, because...well, you might croak. I know, I know. Sorry, I couldn't pass up the pun.

What is also interesting is these colors have been copied by other frogs that are, actually, quite tasty. These frogs use the colors to keep predators away. They're what we call mimics.

My guest today is Molly Cummings, Professor from the School of Biological Sciences, at the University of Texas Austin. She's been studying a particular type of poison dart frog. The strawberry poison frog and has found out that there's more to the story than just bright colors.

She's also been working with a brightly colored beetle called a scarab beetle, and I've been told these beetles have a connection to the movie "Avatar." Let's take a moment to learn about colorful poison frogs and beetles and the story they are telling us about one part of life. Welcome to the show, Molly, and thank you for visiting with me today.

Molly Cummings: Thank you very much, Dr. Biology. I'm happy to be here.

Dr. Biology: Let's start by talking about your cute study subjects. I'm actually looking at them here, and they're amazing. Why don't you talk a little about this colorful, cool and, in this case, sometimes dangerous animal?

Molly: They're very attractive, which is kind of unusual for something that's trying to tell other animals to stay away from it. When we see these colors, they're bright and beautiful and we think, "Wow, how gorgeous, want to grab them."

That's actually a bad idea. If any of you go down to Costa Rica or Panama and see a brightly colored frog, do not grab it and, by all means, do not lick it, because that's exactly where they keep their poisons, on their back.

We were really interested by why this one species, species means groups of animals that can mate together and make more individuals, why they changed their colors. Some islands have red backs, some islands have yellow, some have green, some have blue. They're all considered the same species.

We wanted to understand why because, when it comes to using colors to advertise, it doesn't make sense to change your advertisement signal. When you're driving down the street and you see a McDonald's sign and you see that golden arch on the red background, you think McDonald's. If McDonald's constantly changed colors, you wouldn't always associate those arches with McDonald's. That's the mystery we were trying to solve.

Dr. Biology: I'm looking at some pictures of your frogs. There are actually three frogs here, brightly colored backs, really bright red. Not being a poison dark frog connoisseur, they all look the same to me.

Molly: That's actually another frog. That's a series of three different species that live in Ecuador. This particular story is a very interesting story because we didn't understand why this non-toxic frog, this very juicy frog, was able to copy these two different types of nasty frogs, but when the frogs overlap, they only copied one of them.

That didn't make sense to us because the one frog that it would copy in this zone of overlap, where all the frogs were hanging out together was the frog that was the least toxic. It was almost close to palatable, tasty.

Dr. Biology: Yeah, tasty.

Molly: It was the least abundant. It didn't make a lot of sense. We ended up doing a behavior experiment where we got chickens involved. We trained some chickens to learn to avoid these two different types of nasty frogs. What we found is that when chickens learned on the less nasty frog, they only avoided that specific frog color.

When they learned on the more toxic or more nasty frog, they not only avoided that particular frog color but they also avoided new colors of frogs. That was really interesting to us. It made us wonder whether or not this was a way where frogs could develop new colors, warn predators, and not get in trouble for it, not get tasted.

Dr. Biology: In this way, they weren't so specialized. It wasn't saying, only avoid red backed frogs. It could be that you learned that, "Hey, if it's a bright color, avoid it altogether."

Molly: Yes.

Dr. Biology: It's amazing to me that they're all the same species but they have developed to have different colors and they're still the same species. What's the story behind it?

When you say they've learned to change, this is overtime. We're talking a lot of time, right?

Molly: Yes, we're talking thousands of years, which actually is a short period of time for evolution. These different islands where the different colors arise have only been in existence for ten thousands of years. Getting back to the question of why there are different colors, there's really two big sources of where we think the variation. The change in color can come from. It can be predators, and it can be other frogs.

Let me take on the predators first. The animals who eat the frogs can be a number of different types of animals. They could be birds, they could be snakes, they could be crabs, they could even be spiders. There are actually stories out there, big nasty spiders eating small nasty frogs. [laughs]

Dr. Biology: Wow, OK.

Molly: All of these different animals I've mentioned have different types of eyes. In their eyes, they have different cells that can see the world differently than you and I. You and I can see the world in one way we see these frogs as beautiful, red, and yellow. But birds actually have more types of cells and see a broader part of the light spectrum then you and I see. And snakes, and crabs see it differently even from these birds.

It's quite possible, and that's one of the things we try to study, is whether or not the different eyes of these different predators are driving the changes in color.

You'd expect that from animals who use colors to warn predators, but what is less expected is that the females, the girls in this species, can have actually have some influence, some say, in the direction of the color. We've been asking the girl frogs whether or not they like the boy frogs who are brighter or a different color then their own local morph. And sure enough the girls tend to prefer brighter frogs on all the different islands, regardless of what color their specific island is.

How this relates to color is, that brightness and color are kind of related. You can become brighter by simply bouncing off more photons on that part of the rainbow, or you can become brighter by bouncing off more photons across the rainbow. By bouncing off more photons you might actually change your color from a deep dark red to an orange or to a yellow or to a green. And if the whole goal is just to be brighter along the way you might change your color.

These two processes I've been talking about have been referred to as natural selection, that where they try to survive being eaten, and something called sexual selection, which is trying to be attractive to a mate. We're finding that both of these processes might be producing the changes in color we're seeing between the islands.

Dr. Biology: Right and it can be at opposites in the sense that if you get really attractive and bright which might be great for sexual selection, so the girl frogs like the boy frogs more, but now the boy frog is much more noticeable.

Molly: Exactly.

Dr. Biology: Is that a problem that, now they get eaten more.

Molly: Right.

Dr. Biology: So there's that trade off going on, but because they're using this different type of light. You brought it up so, we see what's called visible light. It's this rainbow of colors and on both sides there's either UV, which is ultra violet, and then there's infrared. You also mentioned that snakes, a lot of reptiles, are really good with infrared.

Molly: Correct.

Dr. Biology: And there are a lot of insects that are really amazing and they can see in the UV. So what we see and what they see are really different. So what are the frogs seeing then if they're not seeing the bright colors? Is it bright colors or is it ultra-bright colors?

Molly: These frogs, because they're active by day, actually have a visual system somewhat similar to you and I. They have these three types of cone classes in their eyes as do humans, most humans do. That's different from, let's say, birds that tend to have four cone classes and can go into the UV, that you mentioned, and can go farther into the red then we can.

The frogs themselves, and we've done experiments to make sure that they can see the difference in the brightness, as well as we've gone into the eye and evaluated whether or not they're likely to detect this brightness, and sure enough they can. These day frogs can see it.

Now if you compare the eyes of a frog that's active by day, to the eyes a frog that's active by night they're going to be very different. The eyes of the frogs at night have two different kinds of cells called rods, which are types of specialized cells to see under low light conditions, and what's really unique is that humans and most mammals only have one kind of rod, that's only sensitive to one portion of the rainbow.

These frogs that are active by night have two different classes of rods that are sensitive to different parts of the rainbow, and the hypothesis right now -- and some of you out there can go out test it someday -- is determine whether or not they use these two different kinds of rods to see color at night. That would be pretty cool, being able to see color in the dark, which is something we are not actually very good at unless we have street lights to help us.

Dr. Biology: Right, and even if you think you're seeing color late at night it's because you just get enough of the light.

Molly: Exactly.

Dr. Biology: On a moonlit night you really don't see the color.

Molly: That's right.

Dr. Biology: We've got our rods, really good for night vision, and then we have our cones, which is great because it's a 'C' begins with color [laughter] all fits together, so the cones are the ones for color. We actually have on Ask A Biologist a nice story on seeing color. It talks about humans see color and wavelengths of light and actually how some animals, what they're seeing. Because a lot of people think animals, dogs and cats, are colorblind, and they're actually not.

Molly: Correct.

Dr. Biology: Which is interesting. Your cat for example, can see the same colors we can see, but not as strong. They live in what I call a "Pastel world." Back to your frogs, why poison dart frogs?

Molly: They're beautiful. I've always been intrigued by all the different colors in this world. My first intrigue was all the different fish colors in the world. Whether or not, you can predict variation in color in this world. Poison dart frogs are one of the most colorful. Almost every color in the rainbow pops up in a poison dart frog. I was very drawn to understanding this variation out there.

How you catch these guys is you put on rubber gloves, and you literally chase them. Some of the really bright ones are so toxic that they're very bold. They have this, "How dare you even think about picking me up," attitude. It's easy to catch them because they are shocked. You're going to grab them. [laughs] The less colorful ones are less toxic, it ends up.

They're a little bit more shy and want to run away. You have to get crafty. It takes a little bit of practice, but you can track them down eventually, if they don't go hide underneath the log. We also use little rubber Tupperware containers to catch them, so that you don't squash them, and then we poke holes, so they can breathe.

Dr. Biology: I can see that. You're doing this in the night time?

Molly: No. They're active by day. They're one of the rare groups of frogs that are active by day. Most frogs are active by night. That's what's so neat. Their visual system, their eyes have changed to adapt to their daylight activities.

Dr. Biology: Are there more of these species of frogs that are on a different islands? It probably depends on the size of the islands. Are there more reds than yellows, or more blues than greens?

Molly: There're more reds and oranges. The thing is, mostly on the mainland, they're all red red-backed. They're red-backed and blue-legged across Nicaragua, Panama and Costa Rica. Just off this one, what's called an archipelago, which is a small series of islands on the western side of Panama, you have this variation, this changes in the colors.

We have up to 15 different colors more. Over three countries, you have the one species having a red back with blue legs. Then, on this very small little area that expands maybe 10 miles in diameter, you have 15 different colors more, from the blues, oranges, greens, yellows and reds. Most of them are the orange-red theme. That's probably because that's what they look like on the mainland.

The blue is somewhat rare. We actually are thinking this idea that different predators can lead to different colors. Where you find the blues is where you find crabs. Crabs visual system actually favors seeing blue as a conspicuous color, more so than it sees red. We think that that might be a factor.

Dr. Biology: Do the different-colored frogs mate with each other?

Molly: Yes, they do. Females tend to prefer the colors that they grew up in. When you bring them together in captivity, they often do mate, when their offspring are a mixture of those colors.

Dr. Biology: They are?

Molly: Yes.

Dr. Biology: Interesting.

Molly: Yeah.

Dr. Biology: A little bit of genetics, we'll get into another show.

Molly: Yes. [laughs]

Dr. Biology: Do you have to travel often for your research?

Molly: Yes, I get to do a lot of traveling. I travel to Panama for my poison frog research. I get to travel to Mexico to collect fish for my sort tail research. I travel to the Coast of Texas to do some marine work on polarized light. I travel to Florida to do some marine work on polarized light as well. Being a scientist, one of the best perks is getting to travel.

Dr. Biology: I've said that. Anybody listens to this program knows that I'm a big advocate. If you want to see the world and travel, become a biologist.

Molly: I agree. [laughs]

Dr. Biology: The other frog that you work with, I actually have a picture in front of me. It's bright red. There are actually three different types of them.

Molly: Yes.

Dr. Biology: The way I read about it, one is very toxic.

Molly: Correct.

Dr. Biology: One is kind of toxic, and one's tasty.

Molly: That's correct.

Dr. Biology: The interesting thing about it is I wouldn't know one from the other right off the bad. If I did some studying, I'll be able to tell. I can understand why you would want to be a mimic the one that's pretending to be the really toxic one. The one that was mimicking, either the very toxic or kind of toxic one, it did the kind of toxic one.

Molly: Yes. The more toxic one lives in the northern part of the Amazonian Basin of Ecuador, a great place to visit. The less toxic one lives in the southern region. The tasty one that mimics these two lives in both of those regions. When it lives in the north, it looks just like the really toxic one. When it lives in the south, it looks just like the less toxic one.

Dr. Biology: I get it.

Molly: In this area, the small geographic region, you get the two toxic species living together. The tasty one also overlaps in its own. It's in the net zone, where it only mimics the less toxic frog. That's completely what I would call "Counterintuitive." It doesn't make sense. We did these behavior experiments, where we trained chickens to learn to avoid the more toxic one.

We trained another set of chickens to learn to avoid the less toxic one. Sure enough, they learned to avoid both frogs. We asked the chickens, "What would you do when we gave you the new-colored frog?" When we asked the chickens that learned on the less toxic frog, they saw this new frog, and they thought, "Something tasty." They went, and tried to eat it.

When we asked the chickens that have learned on the more toxic frog, they would do with the new-colored frog. They looked at it, and they got scared. They didn't want to eat it. We thought, "This makes sense because now, any of the tasty frogs, the mimic frogs that look like the less toxic frog now get 100 percent protection."

Because they're protected from any predator who is familiar with the less toxic frog, because it will avoid something that looks just like it. They get protection from any predator who is familiar with the more toxic frog, because they avoid new-colored frogs. It's a clever way to avoid being eaten. It's a little complicated, but it's clever. Often, biology is like that.

Dr. Biology: Besides the cool colorful and dangerous frogs, you've been working with some beetles. We've seen some cool beetles in some of the work we've been doing. You've been working with the scarab beetles. I actually describe them as almost like colorful, chrome-plated beetles. Very jewel-like. There is an article that you wrote with another scientist. It deals in particular with these scarab beetles and the movie "Avatar." Let's talk a little bit about scarab beetles in Avatar.

Molly: What is the connection? The connection between these scarab beetles and Avatar is the material they have on their carapace, the back of their shiny backs, is the same kind of material that is in place for filters to see 3D.

What these filters do in the carapace of the beetles is they do something, and this is a very science term, but it's called "They face-shift the light." Polarized light is something that our eyes absorb. When you go out and look on a lake, or river on a bright, sunny day or the ocean, you see what we call "glare" that's bouncing off at a certain angle, up and very bright into our eyes. That is actually something called "Polarized Light." Polarized light is simply when the vibrational plane of light, so light acts like a wave.

[crosstalk]

Dr. Biology: Like water or anything else?

Molly: That's right. Light from the sun has waves that are coming in all different types of directions. When these waves, when the light particle hit specific materials, such as water vapor in the sky, it favors certain directions of the traveling of those waves.

When light hits the water surface, a lot of the vibrational plane, the waves that the light want to go off in a certain direction right alongside of the water surface. That's polarized light. There are a lot of animals out there that not only can their eyes absorb polarized light, they can discriminate the particular direction of polarized light. This is something none of us humans can do. It's really needed.

In fact, a lot of insects use to navigate through the sky. Because as light comes into our atmosphere, it gets polarized, relative to the direction of the sun. It's a great way to navigate, when you can't see the sun directly. You can always follow the polarized light fields. It's common amongst insects to have polarized sensitivity in their eyes.

Not common amongst, we, humans, but somewhat common amongst other vertebrates, such as fish and some birds. These beetles are very unique. The fellow scientist, Perch Brady, was a PhD student in the Physics Department over in University of Texas. He came to me one day, and he showed me these beetles. He showed me these beetles with different filters.

When I looked at these beetles with a naked eye and unaided eye, they were this beautiful, chrome green that you were referring to. When I looked at these beetles with a linear polarizer, they were also beautiful metallic green. When I looked at these beetles with a right circular polarizing filter, they were green. When I looked at these beetles with a left circular polarizer filter, they turned black.

I threw in a couple of terms there that I forgot to explain to you. That was left and right circular polarized light. It's not something terribly common on land. That is even fancier form of light, and that's when the polarized vibrational plane gets slightly fey-shifted, such that it starts moving in a circle, a rotation. That rotation will either go clockwise or counterclockwise, left or right-handed direction.

This usually only happens with specialized surfaces, like the back of these scarab beetles, or underwater at the surface of the air and water interface. We're expecting to see more of this interesting, signaling or camouflage behavior using circular polarized light, when we explore underwater.

Dr. Biology: It's like secret codes.

Molly: It's like having the special flashlight that no one else can see. You can turn it on and off to your friends, and the teacher can't see.

Dr. Biology: Today, when 3D is so popular in stereo images, one of the earlier ways of doing it was using polarized lenses on glasses. Very easily, what it did is you polarize the wavelengths of the light in one direction for one eye, and another direction for the other eye.

Then, you did the same thing for two different projectors that would be superimposed on each other. Because they were in this particular polarized wave in one eye, your left eye can only see the same corresponding wavelength of light, and your other eye can only see the other wavelength. You can get that nice 3D that you wanted to have.

Molly: Exactly.

Dr. Biology: A lot of people have also used sunglasses that are polarized. When you get to that glare, it makes the image much clearer in basically dealing with that polarization of light. On "Ask a Biologist," before I let my scientist get out of here, I always have three questions. These are the real telling-tales of their life. The first one is, when did you first know you wanted to be a scientist or biologist? Was there that "uh-huh" moment?

Molly: According to my mom, she knew I was going to be a biologist before I did, because I kept bringing in dead animals into her kitchen, when I was four or five, [laughs] such as dead rabbits that I've found, bees, or fish when we lived on a lake. I've always been drawn to animals.

The uh-huh moment was when I took a class in college, and the way this class worked is our beginning class, the morning class, we got to be underwater, scuba diving. The entire class period meant looking at animals underwater, and our teaching assistant had a slate with all the scientific names of the animals and plants.

We'd point to a cool organism, and he or she would point to the name of that organism underwater. I fell in love with the world underwater. I knew at that point, I want to work with fish. Since then, I moved on to land. I began as a marine biologist.

Dr. Biology: What do you call the ocean? I have to say that's one of the more popular questions I come to ask a biologist. The next one is a tougher one. I have to take away your teaching, because a lot of people that are scientist also like to teach.

I'm going to take away all your science. You can no longer be a biologist or scientist. You're not going to be able to teach. This is your opportunity to do something you've always wanted to do. If you couldn't be a biologist or scientist, what would you be, or what would you do?

Molly: Wow. I've never really thought about that. When I was younger, I worried about World War III a lot. When I was very young, I thought I'd become a diplomat. We feared the Russians, so I started to learn Russian in college. Right now would be a good time for more diplomacy. Maybe I'll be a diplomat. I'm not sure I'll be very good at it. [laughs]

Dr. Biology: If you can go out there and chase down pores and dart frogs, it's good start.

[crosstalk]

Molly: There you go, facing danger.

Dr. Biology: Handling things gently with care. The last one is, what advice would you have for a young scientist or someone? Not all people get into science early in life. Someone that decides, "I really want to be a scientist." What advice?

Molly: I would advise that you make sure you love your questions. Because in science, as in most places in academia, no one's making you get up in the morning. Your questions have to make sure you get up in the morning, and get you in the lab.

If it's in the field or out in your books, reading about your problem, and you have to be incredibly passionate about the question you're trying to answer. That's my biggest advice because if you're not motivated to find those answers, you're probably not going to find them and not do a good a job of it. You need to be motivated.

Dr. Biology: Find that thing you're really curios about, and that's the one you go towards.

Molly: Absolutely.

Dr. Biology: Excellent. Just for a side note, another question that comes through with our students deals with math. How are you in math in school?

Molly: I was quite good at math, as a youngster and in high school. In college, I took the basic math, and didn't push myself much beyond that. That was fine. I did fine for that. However, I got farther into math and got excited by math, when I went into biology as a graduate student because, then the application came to life for me.

I write my own codes now. I write my own statistics, and put them in the code. Once you get excited about a problem in math and have an application for math, it's right there at your fingertips. It's incredibly powerful. I use math in my models all the time to make predictions about how animals are going to behave. Without math, you are very limited as a scientist.

Math isn't that hard. You can make it hard, but it's really not that difficult. I want to encourage all boys and girls to continue on with math, but particularly girls. For some reason, we end up taking less math than our boy counterparts. That's not going to help us later on.

Dr. Biology: As you said, it becomes a fun tool to learn what you are interested in. If you're curious about a particular animal or ecosystem, it's really great because then, you'll have a type of math, not all math. We don't use all math.

Molly: Correct.

Dr. Biology: That's great. Professor Cummings, thank you for visiting with me.

Molly: Thank you so much, Dr. Biology. This is superb.

Dr. Biology: You've been listening to Ask a Biologist. My guest has been Professor Molly Cummings, visiting ASU from the School of Biological Sciences at University of Texas, Austin. The Ask a Biologist Podcast is produced on the Campus of Arizona State University, and recorded in the Grassroots Studio, House in the School of Life Sciences, which is a division of the College of Liberal Arts and Sciences.

Remember, even though our program is not broadcast live, you can still send us your questions about biology using our company website. The address is askabiologist.asu.edu, or you can just Google the words "Ask a Biologist." I'm Dr. Biology...

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