In the darkness of deep ocean

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*The transcript is slightly modified from the audio for better reader experience.

[00:00:00.210] - Dr. Shivranjani C Moharir

Welcome to the Sharebiology podcast. We at Sharebiology.com make science easy to comprehend and help people get updated on the new developments in scientific research. I am your host, Dr. Shivranjani C Moharir, a postdoctoral fellow from India. And today we have with us Dr. Karen J Osborn from the Smithsonian National Museum of Natural History, Washington D.C. to share the secrets of Ultra Black Camouflage in Deep Sea Fishes, which was recently published in Current Biology. Before we delve into the details, let us know a little bit about Dr.Karen. Dr. Karen did her BS From Andrews University and MS from Western Washington University. She received her PhD in integrative biology, from the University of California, Berkeley. She was a Postdoc at Scripps Institution of Oceanography at the University of California.

Thank you, Karen, for joining us. Now, before we start the discussion on your recent paper to motivate our young researchers, please tell us what inspired you to walk the career as a marine biologist? I read that, you like to scuba dive and were fascinated with the amount of diversity that existed in the coral reefs. So please tell us about it

[00:01:11.520] - Dr. Karen J Osborn

Yeah! So I grew up in Michigan, which is in the middle of the United States. There's no ocean anywhere nearby, but my father was an avid diver, scuba diver, and so I got interested in it because of him. And then when I was in college, I wanted to travel for a year, and all my friends were traveling and going to all these fancy, amazing places and just traveling for fun. And I couldn't afford to do that or anything remotely like it. So I found a program where I could go and teach school for a year. And so I chose Pohnpei , Micronesia, which is an island basically halfway between Guam and Hawaii. So out just in the middle of the Pacific. And I went there because I knew that it would be really interesting culturally, and because I would be able to scuba dive because it should be warm and gorgeous and everything there.

And when I did that, I was struggling in my first year of college to figure out what I wanted to do in biology because I took this big year long biology course, the hardest one that there was. And I thought, oh well I'm done with that. I'll know which area of biology I'm most into. And basically, I got through the end of that, and it's all good. Maybe I'm not so into histology and genetics or something, but everything else is good.

So I went out there for a year and taught high school biology and art, actually, and I went diving a lot every chance I got and was just completely blown away by the animals on the reef. Just all these shapes and sizes and colors that I had never seen before and just was completely amazed. Because they're all basically trying to do the same thing. Right. They're trying to reproduce. They're trying to find something to eat, and they're trying not to be eaten.

But they're doing it all these different ways. And they found that diversity really intriguing. And I wanted to basically study that, and I said I want to study strange animals. And that's still what I'm doing and figuring out how they survive and how they live and how they do all the different things that they do. And so that was the start. And I came back from that year of teaching and did take every biology class I could find that was related to organisms or animals and then just have been pursuing that ever since. Amazed that people pay me to do this. Really!!!

[00:03:44.810] - Dr. Shivranjani C Moharir

That's interesting. So can we say that you turned your hobby into your profession or career path?

[00:03:51.350] - Dr. Karen J Osborn

Yeah. Yeah, for sure.

[00:03:53.450] - Dr. Shivranjani C Moharir

So you must be really motivated to do whatever you are doing!?

[00:03:58.440] - Dr. Karen J Osborn

I am. I like to do it all the time, but I have also lots of other things I like to do too. So it gets a little bit....little hard.

[00:04:06.230] - Dr. Shivranjani C Moharir

Everything comes with a package.

[00:04:08.380] - Dr. Karen J Osborn

Yeah. Yeah.

[00:04:09.940] - Dr. Shivranjani C Moharir

OK, so now let us come to the actual topic of discussion, your research paper, Ultra Black Camouflage in Deep Sea Fishes. Please tell us about the background of this work.

[00:04:21.090] - Dr. Karen J Osborn

Yeah. So I studied I did a masters, looking at the diversity of a project that let me learn all different groups of invertebrate. I really enjoyed that, but I did an internship actually at a deep-sea research institute in California and immediately fell in love with the deep sea and just the immensity of the things we don't know about the deep sea.

Right. There's so much out there that we really you know, you see an animal, and sometimes, I would ask my supervisors and the people who were there when I was an intern, like, what is that? They would say, don't know. Sometimes we see things. We don't even know what phylum they belong to. So for me, that was really exciting because I had done my masters in intertidal biology, where we kind of basically knew or at least seemed like we knew everything and we were doing this, tweaking experiments to learn a little bit more each time.

Whereas in the deep sea, we don't know what the animals are. We don't know what they eat. We don't know how they survive. We don't know how long they live. There are so many questions. It just seemed like there were so many opportunities there to make a contribution, that I just got hooked on the deep sea. So I've been doing that ever since, and I am very lucky to have found a way to do it right. Because it's kind of expensive to do these types of research.

[00:05:42.780] - Dr. Shivranjani C Moharir

Yeah!

[00:05:44.080] - Dr. Karen J Osborn

Where there's a will, there's a way.

[00:05:45.450] - Dr. Shivranjani C Moharir

Yeah!

[00:05:45.990] - Dr. Karen J Osborn

And so I started working on I mostly work actually on worms and crustaceans, as you can tell from my title. But my supervisor for my PhD actually worked on fishes. And so I still go out to sea with him, periodically. Like the midwater biology or deep-sea biology is very collaborative, right? So somebody has time on a ship and with a vehicle and we all kind of, you know, you take your people and then you invite more people to come along to work on whatever you find because you never know what you're going to find. Right!

[00:06:22.560] - Dr. Karen J Osborn

You might be going out there looking for a particular animal or to see some particular thing, and maybe you see it and maybe you don't, but you're guaranteed to see something that's interesting. So you want to have a big group of people that work on different things so that you can make the most of what you do find.

[00:06:36.390] - Dr. Karen J Osborn

I was on a cruise with him, and I had been thinking about the surfaces of animals. So midwater is the open ocean, the deep part of the open ocean. Right!

So it's not near the surface. It's far away from shore. It's not near the sea floor. It's all that water below the surface and above the sea floor. So, the average depth of the ocean is four thousand meters. That is a huge amount of space. Right! And we kind of tend to forget about the animals that are there, but there's a huge diversity of animals there. So we were out exploring that.

One important thing for animals that live there is that there's nowhere to hide. There's no seaweed, there's no coral reef, no rocks, there's nothing out there. So it's very important to be able to hide basically in plain sight out there in the shallower water that is often done by being transparent, and if you are transparent, the light passes right through you and things can't see you. The problem is that if for crustaceans, especially, they have an exoskeleton and the exoskeleton is made out of chitin and that has a different refractive index than water. And so when light passes through water and hits that chitin. It, from a certain angle, is going to bounce off. It's not going to pass straight through.

[00:07:52.920] - Dr. Shivranjani C Moharir

OK.

[00:07:53.400] - Dr. Karen J Osborn

So we were studying these crustaceans that have anti-reflective films on them. Just like on a camera lens or something. And so I was thinking about the surfaces of animals and what the surface does to the light and things. And I was on this expedition with my previous supervisor, Bruce Robinson, and he collected a fish, which is not something we do very often with the remotely operated vehicle, because most of the time the fish can get away from us.

They're much faster. They're much faster than the vehicle. But in this case, we actually managed to catch one and it was fang - toothed, which is a really cool quintessential deep-sea fish with big teeth. And, you know, and I was looking at its skin, and I got really interested in what was going on with its skin because I had tried to take pictures of deep-sea fish before, and usually I just get these really horrible pictures of silhouette!

[00:08:48.670] - Dr. Shivranjani C Moharir

Ok.

[00:08:50.140] - Dr. Karen J Osborn

You can see the eye, but for most of the fish, you just get the silhouette, and I have a very fancy camera system, so my start-up at the museum, I got to buy this really nice camera. And, usually, I can take a picture of just about anything, so I was really frustrated that I couldn't get photographs of these things. So I asked one of my friends who works on camouflage in the deep sea and optics and how light interacts with things.

And I asked him. I said, "Sönke how do Blackfish make themselves so black? Because it doesn't seem to matter how much light; I can use for flashes and all the light disappears, and they just suck it all up completely. They're so amazing". And he said, "Oh! I don't know. Nobody's ever looked". We just assume they have lots and lots of pigment or something there, but we've never looked at that. And so I said, "Oh, well. That's interesting! Maybe we should take a look".

So I started taking skin samples from fish that were being collected for other projects, by other researchers. And so that's part of why it took a long time. Right. Because I just, whenever I was out on a cruise and we would get a fish that was black, would take some skin samples, take it back to the museum, look at it under the microscope, do some scanning electron microscopy, and things like that.

And I started to notice a pattern that we were seeing a very similar arrangement of pigment in the skin in all of these different fishes, and what I find so interesting about this project is that we've sampled 16 different groups of fishes all across the diversity of fishes. There are deep-sea representatives from many of the fish groups that we know, and every single one of them arranges their skin pigment in the same way. And it's very different than how most fish have skin pigment.

And so I kept pushing Sönke, who's a mathematician and a biophysicist. I kept pushing him like, "Look, there's something going on here with their skin! Right? This is not normal. It's not just that they have a whole bunch of pigment out there, and it's able to absorb all the light, but something is going on, so can you model something or do some kind of fancy math? I am not a math person. Do something." "Do some modeling and figure out what's going on with these particles. There has to be a reason that they're all the same size and shape and the way that they're packing and in there."

And so it took a couple of years for him to play around with a couple of different ideas. This, kind of always, has been a side project for us. Not something either of us, normally do. It's just kind of this little hobby on the side.

And after a couple of years, he said, " oh, I've got that! Like, I looked at a bunch of modeling of how they looked at why the moon is so reflective, and the size of the particles on the moon and how they're packed together and stuff". And he figured out this nice model so that we could look at them and figured out that the size of the particles of pigment in their skin are just the right size and just the right shape and packed together in just the right way so that they are super-efficient at absorbing all the light.

So those particles are made out of melanin, which is the same pigment that we have in our skin and our hair and birds have in their feathers and everything. So it's the same pigment, melanin, and it's packaged into small granules called melanosomes, and those Melanosomes are a little bit bigger than most animals', and they're more capsule-shaped. So they're kind of elongate instead of being spears'. And then they're packed in together in layers that are about five microns thick. And what that does is basically the light comes in and any light that's not immediately absorbed would normally be reflected back either to where it came from or in some other direction forward. And it would bounce around a little bit, and then it would be seen.

But in this case, the shape in the packing of those particles is just right so that any light that's reflected off of them goes sideways and they have this very thin layer of all these particles. So if you can keep the light in that thin layer, then it's going to all get absorbed before it goes out.

And that's particularly exciting and interesting! Because ultra-black materials are really useful. They're used in high powered telescopes, camera lenses, solar panels, and things like that, anywhere they want to make sure there's no light bouncing around where it's not supposed to be. But they're really expensive. To make those materials, you have to basically make a physical light trap, something that keeps the light trapped so that the pigment can absorb all of it.

And usually, that means some kind of structure. So like butterfly wings, they have these really cool, little, box-shaped things, where the light goes in, and it kind of bounces around inside that box until it's all absorbed by the pigment underneath it. But what these guys have done is, they've gotten rid of that whole structure to trap light, and they just use the pigment granules themselves. The shape of the granules is to keep the light in with all the pigment and absorb them.

So it's a really simple system. Much simpler than all the other systems that we know of, whether they're manmade or in animals.

[00:14:05.310] - Dr. Shivranjani C Moharir

Yeah, that's interesting!

[00:14:06.640] - Dr. Karen J Osborn

It's really interesting.

[00:14:08.020] - Dr. Shivranjani C Moharir

Another question is," Are there any specific spots or locations on the body of the fish where the area is Darker? Or is it dark allover?"

[00:14:17.910] - Dr. Karen J Osborn

It depends on the fish. That's a great question. Many of the fishes have bioluminescence as well. Bioluminescence is light produced by other animals or other organisms, can be bacteria as well. Often, it's bacteria. And in the deep sea, in the midwater, something like eighty five percent or may be eighty six percent of the animals that are there produce light of some sort. So it's very different than on land. It's more the rule that they produce light than the exception like it is up here on land.

So there's a lot of bioluminescent light, and that is the light this ultra-black camouflage is really effective against, because there are fishes down there that are hunting, using searchlights to find things. And if you think about what the background is there, the background view is complete blackness. Right, because there may be a little bit of bioluminescence here or there. But if you can match that blackness, then you have great camouflage. Another way that the animals use bioluminescence is when they feel threatened by the predators nearby or when they take a bite at them, these animals release bioluminescence to try to light up that predator so that something bigger will see it and come and eat it right before it finishes eating them.

And so that's another case where being black is great, right? Because that part of light that's meant to light you up doesn't do it. And then the third case is, many of these animals have bioluminescence themselves. And so they have like a lure that they hang out in front of themselves and they light it up. But think about that. Most of these animals have these huge teeth and eyes and they're really awful looking. Right? But if you were to hang a lamp in front of this big ugly face, and you want little things to swim and eat it. Right. And they're obviously visual things. If they're coming towards the light, then they're going to see this big ugly face and just not come anywhere near them. And if they're all black, you can hang a light right in front of yourself and they won't be able to see you. So there's a lot of different ways to do it.

So we do see different parts of the body being ultra-black on different fishes, and some of them have the entire body black, such as several anglerfish. There are many fish where the entire body is ultra-black. Even their fins and everything are covered with this pigment. But we also see many fishes, different types of fishes that have like, their belly is ultra black because they eat luminescent things. And while it is digesting something that's bioluminescent, it tends to glow and it really doesn't want to run around with a big glowing belly in a place where it wants to be dark.

[00:16:58.140] - Dr. Shivranjani C Moharir

Yeah!

[00:16:58.393] - Dr. Karen J Osborn

Yeah.

[00:16:58.510] - Dr. Karen J Osborn

And many of the animals that have photophores, they will put a bunch of ultra black material around that photophores so that they can control where the light goes. They want the light to only go straight down. So they put all this black material around it so that it doesn't go other directions and light them up.

[00:17:15.300] - Dr. Shivranjani C Moharir

Yeah. So my next question is, "Did you see any symbiotic relationship between the bioluminescent bacteria and the fish (specimen) that you got?"

[00:17:27.560] - Dr. Karen J Osborn

There probably is, but I don't know. We didn't pay much attention to the bioluminescent stuff other than looking at the patterns of where the pigment was in relation to their bioluminescent organs. Some of them make the bioluminescence themselves, and some of them culture. They have a bunch of bacteria in an organ that makes the light for them. But we didn't pay much attention to that interaction, for this project.

[00:17:53.910] - Dr. Shivranjani C Moharir

Yeah. So being dark and being transparent could be two ways of hiding from either the prey or predator. So which one do you think would be more efficient? Or do you think the depth of the ocean at which the organism is there would decide which one would work better?

[00:18:12.600] - Dr. Karen J Osborn

So You've nailed it! You've answered your own question.

[00:18:15.730] - Dr. Shivranjani C Moharir

I am learning marine biology from you ;)

[00:18:22.140] - Dr. Karen J Osborn

We tend to see transparent animals up in the very shallow water where there's a lot of light. So up where there's still sunlight coming down, because then, when you're up in shallow water and there's light reflecting all around about the particles in the water, the light is coming from all different directions. And so being transparent is incredibly effective then. Because it's very hard to mesh with the background because the background is changing, depending on which angle you're looking at it. Right.

[00:18:45.950] - Dr. Shivranjani C Moharir

Right, right.

[00:18:47.480] - Dr. Karen J Osborn

Being black up in the shallow water is really not good because you stand out like a sore thumb. Everything can see you.

[00:18:58.230] - Dr. Karen J Osborn

But many of these fish that are ultra-black, actually migrate up into shallow water at night. And so in dark, ultra-black for them up there is a problem. And that's when we see them having photophores on themselves because most of the predation happens from below. And so you've got light coming down from above and you've got a black animal and another animal looking out, trying to see its shadow. And a black animal makes a great shadow. So they have usually photophores underneath themselves so that they can mask to they can make light to match the light that's coming down from above.

Researchers are starting to look at how they match that light, and in some fishes there's particular part of their eyes. All they do is look at what the ambient light is and then they can control their bioluminescence to match it, which I just think is so cool!

[00:19:59.810] - Dr. Shivranjani C Moharir

It is! So the fish which you got, whether they are preys or predators, are of intermediate size. Another question is," if a prey evolves to get darker, I suppose a predator also would find ways of finding its prey. In that scenario, what do you think would the Predator do to find its prey?"

[00:20:16.790] - Dr. Karen J Osborn

Well, there's all kinds of interesting ways that the fishes and other predators down there are kind of doing this arms race, right, to be able to find things because there just isn't that much food out in the deep sea. That they're either dependent on chemosynthesis from the bottom and that need to be really close to the bottom or you're waiting for this food to rain down, from productivity at the surface. And so there's so many interconnections between food webs there. So many things eat whatever they find. And many of the fishes that we see here.

One of the fishes that we've measured for this is called the black swallower. And they actually eat fish the same size or bigger than themselves.

They really are the nastiest fish ever. I mean, we had one that was perfectly happy and healthy and a bowl that we collected with the ROV one time, and it was just any time you would move the bowl or put anything in there to try to move the direction, it would just snap at you. It was just like you can tell they just anything that comes near, they just eat it right up.

But there are some really cool adaptations. For example, eyes of Deep-Sea Fish. This is not my area, but I've heard enough from my colleagues. There are all these really cool adaptations to really be able to see, like almost single photons in the deep sea, pick out patterns, and things like that, with these really incredibly well adapted eyes. There also are fishes that use red light to hunt with nothing in the deep sea, except for these fishes can see red light because it's just not a wavelength down there right.

And so there there's all these cool different ways that different animals are figuring out just just getting that little bit of an advantage to be able to find some food or to take advantage of the food when they do find it.

[00:22:07.610] - Dr. Karen J Osborn

Yeah, it's really interesting.

[00:22:09.320] - Dr. Shivranjani C Moharir

Yeah. Life would find its way.

[00:22:11.340] - Dr. Karen J Osborn

Yeah.

[00:22:11.450] - Dr. Shivranjani C Moharir

So are there any specific stages of development or age at which they are darker than they are at other stages ? Or are they ultra-dark throughout? Is anything known about that?

[00:22:25.670] - Dr. Karen J Osborn

Yeah, that's a really interesting question and one that we were not able to address with this project. But I think it would be really interesting to to look at that on some of these fishes, because surely at least many I don't know about the specific species that we looked at here, but oftentimes the larvae or the younger stages occur in shallower water, right where there's more food. At least a few of them are transparent when they're young and that at some point they transition into deeper water and they become more pigmented and and things like that. I mean, pigment is a very dynamic system. That is a really incredible molecule, one that we know the structure of really yet, I mean, we have some ideas of it. But if you ask someone what the structure of melanin is, they can give you some ideas. But they really they don't actually know. And there's a bunch of different kinds of.

[00:23:19.940] - Dr. Shivranjani C Moharir

Oh,

[00:23:20.780] - Dr. Karen J Osborn

But it's a little bit toxic because it's a really strong redox chemical. And so it's packaged inside these Melanosomes. So it's in its own little vacuole, and in then those vacuoles, those melanosomes are made in melanocytes and then they're transferred from melanocytes keratinocytes. And then the keratinocytes migrate out to whatever layer of the skin they are going can go to. In an ultra blackfish, they go right out to the very outer surface, which is a really unusual part.

Usually the the pigmented cells are down deeper in the dermal layers. But in the ultra-Blackfish, they're right at the surface of the dermis and the epidermis is highly reduced. So there's not really anything in between them. You know, they can change these things quite easily, which is, I think, how we can account for 16 or more times, the same mechanism of making themselves ultra black has evolved. Because all the fishes have the same mechanism of making pigment for their skin. It is just a matter how much pigment you make and where you move those cells to.

And it's something that's constantly changing. So when it was fish, it's very easy to actually damage that black outer surface because there's nothing there to protect it. So if another fish comes along and takes a swipe at them, they will scrape it off. And it would be really interesting also to see how long it takes for them to recover that, because underneath the black is all this collagen, like all the structure that's in their skin and collagen is super, highly reflective.

So when these guys get damaged, they suddenly have this really, really bright, really reflective spot on them for who knows how long. They probably they can replace it pretty quickly. But but we don't know.

[00:25:05.340] - Dr. Shivranjani C Moharir

That brings me to the next question. So have you tried to keep these fish in laboratory conditions at the ambient temperatures and see whether the coloration decreased or whether the external conditions affected the pigmentation?

[00:25:21.350] - Dr. Karen J Osborn

We haven't. It would be interesting to do that because oftentimes they do come up in really good condition, especially when we collect them with the remotely operated vehicles or the submersibles. But we don't usually try to keep things in the lab unless we have critical experiment or something that we're trying to do. But we do see that in many other animals.

So the crustaceans that I work on are Hyperiid amphipods and we see them. They come up and they're really dark red sometimes. Because there's no red light in the deep sea, red effectively is the same thing as black. So one of the crustaceans and the worms and the and the squid and things, they're red instead of black, but effectively it's the same thing. So we see these crustaceans, they come up and they're really dark red. And then we work on them in the lab for a little while and they get lighter and lighter and lighter. And by the time an hour or two passes, they're completely transparent.

[00:26:13.710] - Dr. Shivranjani C Moharir

Oh!

[00:26:14.750] - Dr. Karen J Osborn

And it's really cool to look at the cells that control that. So it's the keratinocytes and they look like a mesh or some kind of a web sticking out cell and the pigment is in there and they're just like cephalopod skin. Cephalopod skin is so cool. They have neural control. They can pull all the pigment into a teeny tiny little dot. They can spread it out really quickly, and they have a bunch of different colors of it. So these crustaceans can do the same thing. They're just a lot slower about it. So they can slowly decrease the light. So when they're in light, they want to be transparent. When they're in the deep sea, they want to be dark and highly pigmented.

And so probably the fish would. My guess would be that you're correct. And if you were to keep them in the light, if they survived, that they would probably reduce the amount of pigment that they have because it's quite expensive, I think, to maintain this.

[00:27:12.140] - Dr. Shivranjani C Moharir

Yes, that's true. So does the thickness of the layers matter, for reflectance? Does it have to be like you said, five micron or something?

[00:27:24.600] - Dr. Karen J Osborn

Something like that.

[00:27:25.230] - Dr. Karen J Osborn

5 or 0.5 I missed that

[00:27:26.880] - Dr. Karen J Osborn

I don't remember. Don't quote me on that one. One or the other, anyway. Five something. It's not very thick, though. It's really thin, the layer. So there are different thicknesses in different fishes of that layer. And only up to a certain point does it make a difference on how effective they are. Once you get past, whatever that is, five microns, I should look it up for you. Once you get past that thickness, it doesn't matter. The layer doesn't have to be very thick for it to work really effectively. So.

[00:28:02.650] - Dr. Shivranjani C Moharir

Yeah, that's interesting!. So this reflectance is lower than that of the blackest known animals. Just to give a perspective, how can it be compared with any manmade material? Can you just give an example that this material is this dark, something like that?

[00:28:19.600] - Dr. Karen J Osborn

So the best, the blackest manmade material that I know of is Vantablack, which is made by Surrey Nanosystems in somewhere in England. And basically, it's a set of, they grow carbon nanotubules, and it looks like a carpet. They just pack all these nanotubules together and the that light goes into bounces around in these tubules, and it never comes out. And that is 0.05 percent of light reflected back. And we had. One of the anglerfish was indeed that black as well, so there as black as Vantablack for blue and green light. Which is so cool because that's what most of the bioluminescence that's out there has blue and green wavelengths. And so it's really cool that not only are they super black, but they're super black in the particular wavelengths that are important to them.

But yeah, Vantablack is really cool material, but it's super expensive. Like we tried to get a piece of it so that we could calibrate our spectrometer, so we could be sure that our reflectance as we were measuring was good and believable and it's something really expensive and it's really delicate material. So those Nanotubules, like if you touch it, you brush your finger across it, you've just decimated that whole streak there. So the fish are not that fragile, which is cool.

[00:29:39.790] - Dr. Shivranjani C Moharir

So do you think this dark color and minimum reflection of light have implications in prey-predator relationship? So at deep ocean where there is very little light, apart from visual cues, are there any other cues which govern the communication between the same species? What all other cues are there? Apart from the visual ones?

[00:30:05.800] - Dr. Karen J Osborn

Absolutely. Yeah. So a lot of these deep-sea fishes, if you look at their their faces oftentimes and down their bodies. Many of them have a lateral line system so that they can feel the water movement. So it's an touch system or mechanical sensory system. But if you look at the faces of many of the deep sea fishes, they have all these really amazing pores and sensory structures all over their faces. As they're swimming, they push the water through these channels and they have chemo sensory sensors in there. They have mechano sensory sensors in there. So, in the deep sea where it's completely black, you have a couple of different options. You can either make really good eyes and maybe make some light to help you see or you can say, OK, forget it, I'm not going to mess with eyes. I'm just smell on my way around the world and have really good chemo-sensory structures and many of them do that. Or you can say, look, I'm just going to feel everything out there that has to move at some point and I'm going to focus on moving things that move. And so I'm just going to feel things near me. Oftentimes there's some combination of all of those things, but there are a few fishes that just have these incredible chemo-sensory structures and pits and channels to make the water kind of concentrate smells and stuff for them, and it's really cool.

So there definitely are other ways to do things than visual predators. But considering how dark the habitat is, it's really amazing how many animals still retain eyes because eyes are incredibly expensive tissue to maintain and the nervous tissue to translate that information and stuff to. It's all built like some of the most energetically expensive tissue to maintain. So if, like, for example, the crustaceans I work on, I work on them because they have amazing eyes, like sometimes thirty five percent of their body is eye.

[00:32:02.470] - Dr. Shivranjani C Moharir

Oh,

[00:32:03.830] - Dr. Karen J Osborn

so they're dedicating a huge amount of energy to building and maintaining these eyes so that they can see. And that's that's an interesting, interesting choice. I mean, it's not a on the individuals part, but evolutionarily that lineage has gone in that direction. So that vision, they're really depending on vision for everything. And so it's interesting to see those trade-offs in the deep sea, but there's not a lot of energy to be had. And so everything is really, really tight. And I think that's why we got this ultra-black material. They are making themselves ultra black. They're using the least amount of material and the cheapest material they can make, so that they can use as little energy as possible to be effective in their camouflage.

[00:32:48.180] - Dr. Shivranjani C Moharir

What about the size of the eyes of the fishes which you got, the ultra-black fish?

[00:32:54.680] - Dr. Karen J Osborn

Well, it depends. Some of them have, it is not really a continuum, there's you either have big eyes that work well or you kind of forget about your eyes. So, like, this Black Swallower has this huge mouth and this huge extendable belly and these little tiny, beady eyes. So it's probably just smelling its way around the world, which is interesting. And another thing that I find interesting is that for us, smell and taste are very different things. But in the ocean, smell and taste are the same thing. It's all a chemo sensory stuff. So yes, it's completely commingled, those things. And it's very useful because the ocean is actually really structured and most of these animals are quite small, so the water is not the way that we experience it. It's not this big viscose, everything mixing kind of place. It's very viscous. So it's kind of like swimming through honey.

And so if there's a particle that swam through, that scent trail is quite a distinct trail that they can usually follow through this viscous liquid and track down that particle or that animal or whatever that was there. So it's a really not an intuitive thing for us to think about because it's such a different than the animals down there.

[00:34:15.960] - Dr. Shivranjani C Moharir

Yeah. So this low reflectance of light can be taken as maximum absorption of light by the animals. So do you think these fish have any specific advantage because of which they absorb the maximum light?

[00:34:30.310] - Dr. Karen J Osborn

Some people have asked me something similar, and I really don't know the answer. But they've said," ok , if they're absorbing all this light, wouldn't that be generating some heat for them"?

[00:34:39.930] - Dr. Shivranjani C Moharir

Heat. Exactly. Right.

[00:34:42.100] - Dr. Karen J Osborn

Yeah, I mean, it may, if it's like a really big bioluminescence or something like that, but it's so cool down there. It's like the temperature of our refrigerators, two to four degrees Celsius. It's really cold. And so there's so little light that I can't imagine it would make much of a difference to them. But who knows, other things that could be really interesting. So melanin is this really cool chemical and it actually absorbs all kinds of radiation, not just visual light, but also lots of really harmful types of radiation.

So under the dome at Chernobyl, there's a fungus that grows that's completely black, that uses melanin to absorb energy from the radioactivity. And that's what the fungus grows on. So it's growing under this giant cement dome with no light, no nothing. It's just using the radioactivity that's there and the melanin to harness that, to grow. And so the melanin absorbs all kinds of all kinds of energy. It also absorbs all kinds of toxic chemicals. It's a really strong redox reagent. So if you have an outer layer of this stuff on you, then that also can be serving to protect them from toxic chemicals that they may encounter or any different kinds of things that they could encounter, which is kind of interesting when you think about, if you wanted to create a material like this using melanin and use it for like camouflage for humans, for protective gear or something. Not only would you be making yourself a nice camouflage for doing things at night, but you would also be protecting yourself from chemical weapons or from radioactive weapons or things like that, which is a really interesting idea

I generally stay as far away as I can from military things, but I was like, OK, if we can protect our soldiers from that, that's a nice idea.

[00:36:43.960] - Dr. Shivranjani C Moharir

Yeah! So there are two applications probably of these ultra-black fish. One is, like you said, generating ultra-black surfaces and the other could be this energy. It is absorbing maximum light, and it can store it in the form of heat energy or store as in... yeah store we can say.

[00:37:05.650] - Dr. Karen J Osborn

Yeah. Sure. It has to. Right. The energy has to go somewhere.

[00:37:10.090] - Dr. Shivranjani C Moharir

Yeah. That's interesting! Ok, one quick question. It might not be related to this study. So how deep have you gone under an ocean?

[00:37:21.540] - Dr. Karen J Osborn

Umm..So I mostly have used, so when I scuba dive I don't usually go past one hundred feet or like thirty meters. But in the submersible I've gone, it goes down to four hundred meters.

[00:37:36.760] - Dr. Shivranjani C Moharir

Oh four hundred meters?!

[00:37:38.390] - Dr. Karen J Osborn

Before I was a graduate student I went on the Johnson Sea Link, which was a submersible previously, and that one goes down to a thousand meters. So we didn't get that deep on my dive.

[00:37:52.090] - Dr. Shivranjani C Moharir

Yeah, but four hundred is still very impressive! You would have got the whole flavour of under ocean life.

[00:38:00.300] - Dr. Karen J Osborn

Absolutely. It's really interesting to sit in there in this particular submersible. The Jago has a big dome window about, I don't know, like two or three, almost a metre, I think in width. And it has a similar dome on top. And so you can as you're going down, you're kind of going too fast to be able to look out the front and but you could look out the top dome and see the light just fade as you go.

And where I've done that work was in off of Cape Verde, where the water is really, really clear. Right. And it was amazing to me how quickly the light that my eyes could see disappeared. So within a few tens of meters, it was quite dark. But I was a little worried about going in them right there. They are Very small spaces. You've got a lot of water around you, you know.

[00:38:47.370] - Dr. Shivranjani C Moharir

Do you have any companion or are you alone?

[00:38:55.780] - Dr. Karen J Osborn

No no. Thank goodness! There's a pilot in there who knows what he's doing right. And he was crazy scientists who come down and are just, like, so excited and interested in this, but I was so excited to see things not through a camera, but with my own eyes that I really never even thought about all the other things that could go wrong or whatever, because it was just so cool to be able to look out and see with your own eyes. It's a very different experience itself.

[00:39:23.610] - Dr. Shivranjani C Moharir

Yeah, it is a very different experience in itself.

[00:39:26.870] - Dr. Karen J Osborn

Yeah. We can do so many things with the remotely operated vehicles. We can go deeper, we can stay longer, we can collect more stuff because you really don't have to have all that life support material and everything. But there's something about seeing it yourself and actually watching the interactions. And you can turn the lights off and our eyes can see all the bioluminescence and everything happening. But cameras that can see that are really expensive. And so we've only just gotten that the last several years.

But it was really cool to just turn all the light. At one point we had to turn the lights off because there are so many animals attracted to the light. So we couldn't really see anything out there. They were just krill and high parrots all swarming around the front. And so we turned all the lights off completely and then we watched them all bioluminescence, as they dispersed away from the submersible. And it was just amazing to be able to see all of that activity and stuff with your own eyes.

[00:40:20.790] - Dr. Shivranjani C Moharir

Dr. Karen, thanks for taking us to the depths of the ocean to experience the secrets of deep-sea life. It felt surreal! Since we are at the end of podcast, we would like to conclude this episode with your message to young researchers.

[00:40:34.600] - Dr. Karen J Osborn

Yeah, so when I did my undergrad study, I remember how we were taught biology, which is kind of you know, you can look up the answers to a lot of different things. And I didn't really find it that inspiring because it felt like we do everything right, which is obviously not the case. And we know that the pandemic is really bringing that home, like, really strongly. But I think it's really important to instill in students that there's so much to learn and so many interesting things that we just don't understand that we don't know about. And that is most clear in the deep ocean, because there are so many things. I give talks at a lot of different places, to a lot of different audiences. And I always get really wonderful questions and most of the time I can't answer half of them. Not always, because I don't know the answers, but just because we don't know what these animals eat. We don't know how they survive. We don't know how long they live. We don't know what cool things they are doing that we could learn from to make something that would make our lives better, and so I think it's really important that we continue to make it possible to do exploratory science. Where you're just out there looking and seeing what makes you curious, what makes you ask questions. And that for students, I think is the most important thing. That they ask questions and that they realize that they can make a difference. There's so much to learn and so much to contribute.

[00:42:12.770] - Dr. Shivranjani C Moharir

Dr. Karen, it was a pleasure to have you as a guest. And we look forward to the opportunity to do so again.

[00:42:19.030] - Dr. Karen J Osborn

Thank you guys so much for the invitation. Good luck.

[00:42:21.690] - Dr. Shivranjani C Moharir

Well, listeners, we hope you too vicariously experienced the life at the depth of oceans. And if you like our work, please subscribe to sharebiology.com for more podcasts in the future.