IRA FLATOW: OK, lots of people have questions. Let's go to our first one.

ERIC: Hi, my name is Eric, and I was taken by Ira's comment that they were not tentacles, they were arms. So can you tell us what the difference is? What makes them one or the other, please?

IRA FLATOW: Sir? Why don't you take that? Yeah.

BARRETT CHRISTIE: This is a great question. Everybody always defaults to tentacles when we're talking about cephalopods. The distinction between a tentacle and an arm is what the animal uses it for primarily. It's more behavioral than anything else.

So if it is a multifunction appendage, like on an octopus, if they can use it to capture prey and mate with their opposite sex, and they can use it to mix cocktails and pick locks and everything else they might do with that arm, that becomes an arm, because they're using it for more than one function. If it's expressly an appendage they use for prey capture-- like in a squid, they have the arms, but then they have two tentacles, or in a cuttlefish, that will shoot out and grab the prey. Those are tentacles because they're used for one purpose and one purpose only, and that's prey capture.

And there's differences, as well, in the arrangement of suckers and hooks and how it works. And an octopus, the super interesting thing is you can tell-- show of hands, who knows how to tell the difference between a male and a female octopus? Nobody, just me.

IRA FLATOW: That's why you're here.

BARRETT CHRISTIE: If you look at it from the top down, you have right arms and left arms. If you look at the third right arm, it will be slightly different than the rest in a male. And that's called the hectocotylus. That's what it uses to grab its sperm packet and transfer it to the female, and that's how they breed. So if you look at the third right arm on an octopus, and it looks different than all the others, you've got a male. If it looks the same, you've got a female.

IRA FLATOW: Wow. We need to talk later about the cephalopod that mixes drinks, but we'll get to-- yeah, go ahead.

CHRISTOPHER WHALEN: Yeah, if I could just add to that, the other unique thing about tentacles is they're only in squids, cuttlefish, and their relatives. It's actually a very unique evolutionary characteristic that defines that group, in part.

IRA FLATOW: Very interesting. Next question over there.

AUDIENCE: Do octopuses see color differently?

IRA FLATOW: Oh, good question.

BARRETT CHRISTIE: That's another excellent question. So octopuses have the same range of color that we see. So they can see all of the colors represented here in the room, but they can't tell the colors apart. So functionally, yes, they are colorblind. But they're not like a lot of species that are colorblind, where they don't see red, or they don't see blue at the other end of the spectrum. They can actually see all these colors. It just looks black and white.

However, the super interesting thing is they also see polarized light, like you would see through polarized sunglasses. And we're seeing some recent literature-- I say recent. In the past 10 years, we're seeing some literature that the cuttlefishes and the squids can actually communicate with each other using polarized light. So they can make patterns on their bodies and send a signal to each other like, hey, back off, or hey, I want to meet with you, that we can't even see with the naked eye. Only they can see it because it's only represented in polarized light.

IRA FLATOW: Cool. Yes, question please.

AUDIENCE: So the video mentioned how neurons are in the octopus's arms. So if that's so, do the arms ever get in conflict with each other, since they all have individual movements?

IRA FLATOW: Ooh. We have a young researcher there, to be.

BARRETT CHRISTIE: All the time. And you heard them mention that sometimes they're behaving contradictory to each other. Sometimes you'll even see arms-- you'll give an octopus a shrimp or a food item and they'll grab it, and another arm will try and fight them for it. So you do see that.

And the really interesting thing is that they have those little brains. They talked about how many neurons. An octopus has roughly the same number of neurons in its body as a mouse, which is astonishing for an invertebrate.

But because they have, basically, a little mini brain-- we call it a ganglion-- in each arm, the arms can make decisions for themselves. And even if you cut the arm off of an octopus, it will still reach for prey even once it's severed from the body, because the arm itself is making the decision. And they're hardwired to do certain things, like grab prey when the opportunity arises.

IRA FLATOW: How long does an octopus live for?

BARRETT CHRISTIE: It depends on the species. The longest-lived octopus in the world that we know of is Enteroctopus dofleini, the giant Pacific octopus, the species we have here on display, which is sleeping right now, unfortunately. As everybody was here, it was curled up in its cave. Hopefully some of y'all saw it.

Enteroctopus dofleini lives for five years at the most when it's in very cold water. Now, these animals, like fishes, they're poikilothermic. They're what we would call cold blooded. So their metabolism slows way down, their growth slows way down, and their lifespan gets longer, usually, in colder water.

These animals range all the way from the California coast up through the Aleutians to Japan. So the ones we see that can live for five years, the absolute maximum, are way up in very cold water. Most giant Pacific octopus will live around three years max, which is still exceptionally long for a cephalopod. Most smaller octopus that you'd find in warmer water only have a lifespan of about a year. And the really small tropical species, like the blue rings that are deadly, they live three to four months tops.

IRA FLATOW: Wow. Next question.

AUDIENCE: What's the difference between a octopus and a squid?

IRA FLATOW: What's the difference?

CHRISTOPHER WHALEN: I can take that. The easy difference is the number of arms. Squids always have 10 arms. Octopuses, eight arms. So if you can just count them, you can tell them apart.

IRA FLATOW: OK, next question.

VALERIE: Hi, I'm Valerie. I'm a science teacher from Woodbridge, Connecticut. And I'm curious about the relationship between the nautilus and the non-shelled cephalopods. Is the nautilus the ancestor of the squid, the octopus, and the-- what's the third one? Cuttlefish.

And which one came first? Like, when the shell-- if the shell was discarded and we had evolution--

IRA FLATOW: Yeah, why does one have a shell?

VALERIE: Yeah.

BARRETT CHRISTIE: Yeah, so all mollusks ancestrally have a shell, and that includes cephalopods. And most of the fossil record we have of these are their fossil shells.

Nautilus, this is an active debate. Nautilus split from other cephalopods, at a minimum, 400 million years ago. Alternatively, more like 500 million years ago. And this is an active debate.

But those early relatives of squids and octopuses would have also had an external shell. And then around 380 million years ago, that external shell becomes internalized, more or less like your bones. And most cephalopods today still have either that internal shell or a remnant of that internal shell.

So it is-- nautilus is a good way to understand what the ancestors of the other cephalopods looked like, but it is not itself an ancestor of those cephalopods, if that makes sense. And it has some unique characteristics that are just a nautiloid innovation, like the number of arms. If you look at a nautilus, they have something like 90 appendages. And that's not the ancestral condition. That is a unique innovation of that group of animals.

IRA FLATOW: 90 appendages.

BARRETT CHRISTIE: Something like that, yeah. I don't know the exact count. I don't know if--

IRA FLATOW: It's close enough for government work. OK. Yes, next question, young man.

AUDIENCE: Why do squids have that speary thingy, like that sharp tentacle?

IRA FLATOW: Why do squids have that sharp tentacle, you know?

BARRETT CHRISTIE: Oh, so that's the tentacle we were talking about. The short ones are the arms, and they use those for multiple functions. The long ones that jump out and grab the food are the two tentacles. And that's what they use to capture prey.

They'll capture it with that, and then they'll draw it in. And if you think about a huge deep-sea species like Architeuthis, the giant squid, they can be very, very long. But they capture the prey out away from the body, and then they bring it in. And then they use the arms to manipulate it and to kill the prey and then to eat it.

IRA FLATOW: Did Jules Verne know anything about these giant squid? Because they were in 20,000 Leagues Under the Sea.

BARRETT CHRISTIE: I think he must have.

IRA FLATOW: Yeah. Do we actually see them living, these giant squid, or--

BARRETT CHRISTIE: So up until-- for most of my lifetime watching, you know, documentaries on the Discovery Channel and listening to Science Friday, most of my lifetime, we had never seen a live Architeuthis, the giant squid. And it's only been in the past, what, 10 or 15 years that we've actually seen them on camera for the first time. And it seems like as soon as we figured out how to find them, we opened the floodgates. There's been a deluge of giant squid video in the past decade or so. So we have seen them.

IRA FLATOW: Yeah. Let's go to the next question.

AUDIENCE: I have two questions. So can I do them?

IRA FLATOW: Go for it.

AUDIENCE: OK, so my first question is, how many cephalopod evolutions have you recorded?

CHRISTOPHER WHALEN: So that's a tricky question to answer. I guess I'll cheat a little bit and say that everything is always evolving.

AUDIENCE: Not like recorded, like, by video, OK?

IRA FLATOW: How many have you photographed? Video? Is that right?

CHRISTOPHER WHALEN: I personally haven't photographed any--

AUDIENCE: I mean how many do you know about?

IRA FLATOW: There you go.

CHRISTOPHER WHALEN: Yeah, maybe you want to take that?

[LAUGHTER]

IRA FLATOW: I told you, kids ask the hardest questions.

BARRETT CHRISTIE: As the evolutionary biologist passes the torch to me. OK. So we have-- I couldn't put an exact number. There's a lot of species around today. And each one of those species has evolved independently, but we haven't actually seen that happen, which is why the work that Chris does is so important.

We see the living animals. I can work with an octopus or a nautilus or a cuttlefish today and know how it behaves and know how it acts. But we don't know where it came from. So that's where our work with living animals can yield some clues, and then Chris's

work with the fossil animals can kind of put all the puzzle pieces together until we have enough of the puzzle pieces-- even though in science there's always some missing-- that we can hopefully see what the picture is supposed to be.

CHRISTOPHER WHALEN: I don't know if this helps, but a common thing we say is that 99.9% of all species are extinct. So you take everything that's alive today and think that, for the last 500 million years or so, you had a similar number of things living. And then they've all died and been replaced for hundreds of millions of years.

IRA FLATOW: OK, next question.

AUDIENCE: OK, so my second question is, how many new species have you found in the past 22 years?

[LAUGHTER]

IRA FLATOW: I did not put him up here to ask-- I didn't put him up there.

CHRISTOPHER WHALEN: Very specific timeline there.

IRA FLATOW: Not 23, not 21.

CHRISTOPHER WHALEN: Well, I personally have only described one new species so far. But in science, we're discovering new species all of the time, both living and extinct. I mean, that's one of the main things you do, actually, if you go into zoology, invertebrate zoology or vertebrate zoology, or if you go into paleontology. There's still a lot that we don't know.

IRA FLATOW: And maybe you'll find more. You know? Maybe you'll go out there and find more yourself. Next question.

AUDIENCE: Why do octopuses have eight arms?

IRA FLATOW: Oh.

CHRISTOPHER WHALEN: Yeah, so that's a good question. So we said that ancestrally, they had 10 arms, OK? And then we've got something that's like a vampire squid. This characterized all relatives of octopuses for a good interval of time. The entire time you had dinosaurs on Earth, the relatives of octopuses sort of looked like a vampire squid. And so they reduced two of those arms to these filaments.

For whatever reason, those filaments were no longer useful to the group that became modern octopuses. And in evolution, when something isn't useful, it's very quickly eliminated, because every structure on an animal is an investment in energy and

resources to maintain that structure, which it's better to save if you can. This is why, as sort of an anecdotal example, if you stop working out for a month or two, you'll notice you lose some muscle mass. And that's your body saving that energy because it thinks, well, you're not using these muscles, let's not waste that investment into them.

IRA FLATOW: Interesting. Next question, please. Yes.

ASA: My name is Asa, and I have two questions. The first question is about how there are many brains in all of the tentacles. So to move from one place to the next, do all those brains have to work together?

IRA FLATOW: Great question.

BARRETT CHRISTIE: No, and sometimes, even if you watch the videos, sometimes you'll see one arm trying to go in a different direction while the animal is trying to go in one direction.

IRA FLATOW: So who decides which direction, then?

BARRETT CHRISTIE: Ultimately, the central brain, the real brain, can overrule all of the ganglia, that we call them, the little brains in the arms. So ultimately, the central brain can overrule that. But like you heard them say, their neurons don't fire as fast as ours. So it's much slower to get a message from brain to the tip of the arm than it would be for a vertebrate. So usually, the main brain will rule out, but sometimes it takes it a minute to overrule and figure out which direction.

IRA FLATOW: We've also seen the octopus grab something really quickly. There must be tremendous coordination, then, of those little mini brains. What decides, hey, we're going to all coordinate and do that? Is it the main brain?

BARRETT CHRISTIE: I think it's probably a combination of both. It's probably a combination of-- we heard them talk about they have chemoreceptors. The best way to get an octopus to play something is to rub it with a piece of shrimp, because they can sense that with their arms. So it's probably a combination of each individual arm sensing, hey, there's prey here, hey, there's something I should grab onto, and the central brain directing it to then envelop that prey and eat it.

IRA FLATOW: Interesting. Next-- you have another one, you said?

ASA: Yeah. So for the eyes, are all of the brains connected to it to know where the prey is?

IRA FLATOW: Whoa. Whoa.

BARRETT CHRISTIE: Another--

IRA FLATOW: Deep thoughts.

BARRETT CHRISTIE: --excellent question. The brain is connected to the eyes, yes. But only the central brain is connected to the eyes. So they're only seeing that.

And a lot of what you'll see octopus do is called speculative feeding. Speculative feeding is just a fancy word for, it's taking a wild guess. It'll pick a rock, it'll pounce on a rock, and it'll completely cover it on the off chance there might be something there, because it can't see it and it can't really know if there's a crab under the rock until it feels under. So the eyes only connect to the central brain, but not to each of those ganglia. They're just working off taste and touch and scent and taste.

IRA FLATOW: Terrific. This is interesting stuff. Yes. Next question. See if you can top those questions.

SARAH: I can't. I'm Sarah, and I have been watching deep sea documentaries with my son since he was two, and he's heading off to study marine biology in the fall. Very happy. My question is about octopus behavior. They tend to be solitary, from what I understand. Do they have preferences for certain people or certain other octopuses? Do they get along with others, or seem to have favorites?

BARRETT CHRISTIE: Most species-- there are a few species that can be kept together. Octopus chierchiae is one that they're working on up at the Woods Hole at the marine biological laboratories. But almost every octopus species, as a general rule, if you put two of them together, you're only going to get one. They will cannibalize each other. Sometimes the females will cannibalize the males right after mating, because at that point, what's the purpose of having the male around anymore?

So they will-- most species will cannibalize each other. They generally don't like to be around other octopus. In fact, a very interesting experiment is to show an octopus a mirror. They'll get angry.

They don't recognize it as themselves. They'll actually start to get angry. They'll turn bright red. Their ventilation rate, their breathing rate, basically goes through the roof. So they don't like being around other octopuses.

But yes, they actually do-- the other part of your question, they do recognize us human caretakers. And they do have preferences. When I worked at an aquarium, Moody Gardens in Galveston, I worked with an octopus one time.

There were two of us that maintained this gallery where the octopus was. The woman I worked with, Betsy, the animal loved her, had no problems with her. Every time I opened the lid, it would squirt out about a liter of 50-degree freezing water and soak me. For whatever reason, did not like me whatsoever. So they absolutely do have preferences.

IRA FLATOW: Will they not maybe eat from one person but get fed from another?

BARRETT CHRISTIE: Certainly. They're generally indiscriminate. They'll generally take food when it's offered from anybody. But they're much more readily-- will much more readily feed from certain caretakers.

IRA FLATOW: Really interesting. Yes. Next question.

GABRIELLE: Hi, I'm Gabrielle. I'm a plankton ecologist. And so I'm really interested-- we started with a vampire squid feeding on marine snow. Really curious if you can speak to-- is that a recent evolution, recent, to feed on that detrital matter from the upper photic zone? Or is that something that's always been the case for those organisms?

CHRISTOPHER WHALEN: Yeah, so there's this idea in evolutionary biology that the deep ocean is a refugium. So when you have a mass extinction, if you happen to survive in a deep ocean environment, you're more likely to get through. And so we tend to see a lot of these living fossils in those deep settings.

So there's no expectation that most of the ancestors of octopuses would have done that. I said a lot of them would have been like vampire squid, but not in terms of diet. Vampire squid having that diet is probably just the ticket that made it through the Cretaceous-Paleogene mass extinction that killed off the dinosaurs, killed off the ammonites, another group of cephalopods, but also killed off most of our fossil octopuses. They were probably a lot more diverse before the dinosaurs went extinct.

IRA FLATOW: Fascinating. Next question, please.

AVA: Hi, I'm Ava, and I was wondering, what does the word cephalopod mean?

IRA FLATOW: Yeah.

CHRISTOPHER WHALEN: So it means "head foot." I can't say exactly why it was given that name, but that's what it means. And I think it's pretty appropriate, since they're the most intelligent mollusks by far, if you think of a clam, but also the most intelligent invertebrates.

IRA FLATOW: Is it Latin?

We'll Google it. We'll Google.

BARRETT CHRISTIE: Latin or Greek would be a safe bet.

CHRISTOPHER WHALEN: One of those two.

IRA FLATOW: OK, next question. They're all such great questions. Yeah.

MATTHEW: Hi, my name is Matthew. And I was looking at the small cuttlefish downstairs, and I saw that they were rapidly changing color. And I was wondering why. Like, is it their mood, or is it something else?

BARRETT CHRISTIE: That's a fantastic question. So hopefully everybody got to see them. They're very, very small. But we do have flamboyant cuttlefish, one of the same-- the very colorful species we saw in the video. And what you're seeing most of the time when you're seeing a change in color, there's a couple different things that could be happening.

They can be signaling to each other. If the whole body is changing color or if you're seeing like this wave pass over them, that's far more common. That's actually called a passing cloud display. And I'm not an expert in behavioral science, but the most recent papers I've read on it, we still don't know exactly what it means.

It could be signaling to another animal. It could be signaling danger. Could be signaling-- communicating that they need to move or to feed or to mate somehow. We honestly don't know what it is.

Or it could just be that animal trying to blend in with the bottom. So if you've ever been in a shallow ocean area, or even a swimming pool, you've seen what we call glitter lines, those little wavy lines that go back and forth across the bottom of a pool. It could just be the animal trying to camouflage in with the light that's being refracted as the ocean surface boils up and down.

IRA FLATOW: They are the most amazing at mimicking their environment. If you want to see a great film that we did many years ago called Where's the Octopus? it's on our website, sciencefriday.com. It's the most amazing-- trying to find this octopus in the film, it's like Where's Waldo?

And you watch this octopus change shape and color, and it surprises the marine biologist. He, like, gulps on his scuba diving outfit as it just surprises him, too. Where's the Octopus? Great video. Yes. Next question.

NOAH: Hi, my name's Noah. I was wondering, so you know how starfish, like, if they were to lose an arm, they could regenerate their whole body from the arm? Since octopus have a good regeneration system, are they able to do something like that?

BARRETT CHRISTIE: Absolutely. They can't regenerate their whole body from just one arm like a starfish can, but they can easily regenerate arms, especially the younger they are. What happens in a lot of cases, if an arm gets damaged, it will either grow back kind of stumpy looking-- so it doesn't look quite right, but it does grow back and it's functional-- or in some cases, it will actually bifurcate, which means it splits in two. And in that case, you actually get a nine-arm octopus, because that one arm will split into two, and it'll grow two new arms from the wound.

IRA FLATOW: Next question. Where's the question? There.

PAUL: Hi, my name's Paul. Would you say that cephalopods are the smartest animals in the ocean, or certainly one of them?

CHRISTOPHER WHALEN: Probably not the smartest animals in the ocean, but one of them, because you've got to remember you've got dolphins in the ocean, too, which are, I think, usually considered the smartest animals besides primates.

BARRETT CHRISTIE: Yeah, I would say that they are by far the most intelligent invertebrate. But remember, whenever you hear people talk about cephalopods, you always hear that qualifier, invertebrate. There are far more fishes, dolphins, marine mammals that are just an order of magnitude more intelligent.

Your dog at home, or even pigs-- pigs are highly intelligent animals. Dogs and pigs are way more intelligent than cephalopods, which doesn't diminish how amazing they are. They're by far the most intelligent invertebrate. But they don't really rank up there with the dolphins.

IRA FLATOW: Wow.

BARRETT CHRISTIE: They're cooler than dolphins.

IRA FLATOW: They're cooler.

BARRETT CHRISTIE: They're just not more intelligent--

IRA FLATOW: But they're cooler.

BARRETT CHRISTIE: --than dolphins.

IRA FLATOW: All right. I think we have set the record for the number of questions from the audience in a Science Friday segment. Thank you all.

[APPLAUSE]

I want to thank-- I want to thank our guests, Barrett Christie, director of animal husbandry at the Maritime Aquarium here in Norwalk. Christopher Whalen, postdoctoral research and invertebrate paleontologist at the American Museum of Natural History in New York City. Thank you both so much for being here this evening.

[APPLAUSE]