Echinology with Rich Mooi
Ologies Podcast
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Oh, fun fact about this episode: it's all about sea urchins but at the very end, we put a little bonus episode for you and it's all about electric vehicles. I've long had a passion for them, I also like to get away from driving fossil fuels, I have an electric vehicle. So, I got a chance to talk to an up-and-coming science communicator, he has a podcast called *StarTalk* and we discuss electric vehicles and the possibilities around them. So, that's at the very end of the episode. But, onto sea urchins.

Hi, it's your best man's brother who makes really good kabobs, Alie Ward. Let's dive into the sandy sea bottom, shall we? Let's gather some facts about water hedgehogs. This -ology is echinoderms, specifically, sea urchins and sand dollars, this is a wild one. *Ekhînos* in Greek means hedgehog. Urchin: Latin for hedgehog. Water hedgehogs. So, I got into, physically, The California Academy of Sciences for this one. That's right, it's an in-person interview.

Alie: Hello, Rich!

Rich: Welcome to sea urchin central. You've had quite a morning!

Alie: I'm soooo excited!

I had just flown up an hour before to San Francisco. I raced to The Academy and I was balancing a cafeteria coffee and a tiny, old Mervyn's leather purse, with all my sound equipment. I had just gotten a negative PCR, things were good, we had some face-to-face communication with one of the world experts in this field…

Alie: I hope you're ready to talk sea urchins.

Rich: Oh, I'm never ready to talk sea urchins. [*Alie laughs*] I hate those things.

…who we will meet in a sec, but first, thank you to everyone at Patreon.com/Ologies for supporting this show and everyone who has ever left a review for this show which keeps it up in the charts. I've read every single one you've ever left! Including one left this week from Little'filly who wrote:

> *This podcast is like the best info dump friend you could ask for… I love you so much that I can even forgive you for throwing shade on shakshukah.*

Little'filly, it's mutual. And shakshukah will be fine without the tomatoes. Other than that, shakshukah, you're trash.

Okay, so this guest, this Echinologist, he has been studying these sea creatures for decades and is now the Curator of Echinoderms at The California Academy of Sciences, Department of Invertebrate Zoology and Geology. And his brain holds more knowledge about how these creatures evolved and how they're related to each other than perhaps anyone else out there.

These critters live on sandy sea floors and rocks from places like Nova Scotia, all the way to Antarctica, and everywhere in between. And he has published papers on populations from Sri Lanka, the Philippines, Morocco, Florida, and more. And most people, if you ask them, "What do you think of sea urchins?" they say, "I don't think about sea urchins." Well, get ready for that to change. You're about to drive down the freeway, just thinking about their butts and hats, aerodynamics, their disembodied teeth, designer sand grains, philosopher's lanterns, the best sushi you have ever had, what it's like for your whole damn body to be an eye. So, please enjoy these waves of

knowledge, crashing all around you, with human delight, curator, researcher, explorer, evolutionary enthusiast, and new friend, Echinologist, Dr. Rich Mooi.

Rich: Oh yeah, it's Rich Mooi, that's my published name, I'm Richard John. And it's he/him. I work in a wide variety of echinoderms. So, the sea urchins are one little corner thereof.

Alie: How would you say…? I mean, we might as well just start, yeah.

Rich: Yeah, sure. Well, echinoid.

Alie: Echinoid.

Rich: Echinoid. The formal name for the group is *Echinoidea*, the "-oidea" ending is a special connotation that it's a larger group within an even larger group. And that even larger group is a phylum and, in this case, we're talking about a phylum *Echinodermata*. And the *Echinodermata* is a group that includes all those familiar, marine, iconic things like starfish, sea lilies… If you've ever heard of sea lilies, they're actually not plants, they're animals that look a little bit like a starfish turned upside down on a stalk, moored to the sea bottom.

Alie: I've never seen or heard of it.

Rich: Sea cucumbers, you've probably heard of those.

Alie: I've heard of them.

Rich: Yeah, sometimes they're eaten; sometimes they're fished for food.

Alie: Their poop is mesmerizing. [*laughs*]

Rich: Their poop is mesmerizing, absolutely. Magic poop.

Aside: A sea cucumber, side note, is so polite; it eats buckets of sand, and it cleans all the debris out of it. And then at the other end, just imagine a tube of toothpaste but with sand. Just on a continuous loop. It *is* mesmerizing. And yes, the phylum, *Echinodermata* contains a lot of different animals, but this episode will be zooming in to both the regular, symmetrical, and the irregular ones because those two are his favorites.

Alie: Would this be Echinoidology if we're talking just urchins?

Rich: Actually, it's kind of a made-up term, but I call myself an Echinologist.

Alie: Perfect. That's not a made-up term, you're allowed to make it up.

Rich: I'm allowed to make it up. [*laughs*]

Alie: Yes, you're one of the most foremost researchers of this.

Rich: All three of us call ourselves that! [*Alie laughs*] No actually, there's actually quite a lot of interest in sea urchins worldwide and there are experts in as far-flung places as Austria, lots of them in Russia… At the moment, it's a difficult topic but I have several colleagues there, with whom I'm missing direct contact at the moment.

Aside: Rich also has colleagues at Scripps and is working via a grant to piece together the evolution and family tree of sea urchins and then cross-check it with fossils.

Rich: One of the great things about sea urchins – and I'll tell you a bit more about what those actually are in a moment – is that they fossilize really well because they have this hard structure skeleton. It's actually a true skeleton so it gets a special name, it's called a test. [*"This is a test."*] And as I tell my students, "Don't let me catch you calling it a shell. [*Alie*

laughs] If I hear you calling it a shell, I'm going to have to hunt you down." But it's actually an internal skeleton. A shell is external; it's secreted by snails and clams and things like that as an external protection. But the test of sea urchins is actually like your skull, in a way; there are internal organs inside that and then the whole thing is covered with skin, there are muscles to operate the spines, all of the other good things that make a sea urchin work in its environment. So, it really is a true skeleton.

Alie: Because it's not the last thing facing the environment?

Rich: That's correct.

Alie: Aha!

Rich: There's actually an interface of skin, epithelium we call it, special name, but it's a skin layer between that test, the skeleton, and the environment itself. Which makes sea urchins kind of special in many ways because the form of that test, tells us a lot about how they live, where they live; because so much of that is reflected in the skeletal structure – in the shapes of the things that sea urchins adorn themselves with – that you can actually see a sea urchin in the fossil record and know almost immediately, by comparison with what they're doing today, what that animal was doing in its environment tens, dozens, hundreds, millions of years ago. So, that makes them an ideal laboratory for the study of major changes in evolution, major evolutionary innovations. I like to say that I study innovation in nature; evolutionary novelty is my shtick.

Alie: Well, what about your history though? How did you… If you're talking your evolution, doesn't quite go back as long as a sea urchin's, but how did you wind up studying these spikey, sand dollary, round, flat, spikey creatures?

Rich: Well, the story goes back a long way. I'm one of those nerdy kids that tripped out on all kinds of ancient books, books that my relatives would send to me because they knew of my interests. And so, one of my favorite books was a book by Rachel Carson, *The Sea Around Us*, and I actually had an abridged version, and I never tired of looking at the pictures in there. So, I knew I guess, maybe, when I was about 8 or 9 years old that I wanted to be a marine biologist.

Alie: Wow, that's so young! That's so convenient for you and your parents and teachers.

Rich: Yeah, it was convenient for me especially, [*Alie laughs*] but yeah, I think people saw, "Oh yeah, a marine biologist, he'll probably stay out of trouble." But the truth is that marine biology for me, in the landlocked city of Toronto, was a bit of a challenge.

Alie: I'm sure.

Rich: So, I lived through a lot of that by reading all of these books and by watching the great Cousteau shows and things like that. [*clip of Jacques Cousteau: "It is not very glamorous, but it is floating, and it is alive."*] So, I'm one of these guys that was actually inspired by people like Cousteau to go into his field of study. I think about the age of 10, or 9, I was drawing the blueprints of the research vessel I was going to have someday. That's been slow to come about, but that's not to say that I haven't had an opportunity to do some amazing stuff out on the field.

I've been on ships in Antarctica, I've been in submersibles, and I've been able to join on expeditions to the Philippines, the latter of which has been a mainstay of a lot of our work here at The Academy to study the health of coral reefs, and sea urchins are integral to that

health. So, I'm really honored to have been able to do that work there with all of my colleagues here who are so concerned about the decline of coral reefs today.

When I was younger, I had this drive to be a marine biologist, but I ended up doing my undergraduate, my graduate studies at the University of Toronto in Canada, challenged by this distance from the ocean. But I did a lot of work with a professor there, a late colleague of mine, a dearly beloved man named Malcolm Telford, who introduced me to the world of sea urchins by way of not only helping to teach the marine field course that we had out in New Brunswick in the Bay of Fundy, where the tides are 30 feet or more.

Aside: Just a side note, the Bay of Fundy is fun indeed. It's right above Maine and I was like, "Are 30-foot tides high? I don't know." I did some piddling around and it led me to the website, BayOfFundy.com, which bears a giant font, all caps, proclamation, "BAY OF FUNDY TIDES: THE HIGHEST TIDES IN THE WORLD!" So, apparently yes, they are a big deal. But marine scientist and author Dr. Malcolm Telford took Rich under his watery wing.

Rich: He was interested at first, at least initially, in these little crabs; there's these tiny little crabs that are parasitic on sea urchins.

Alie: [*sharp inhale*] How small are they?

Rich: They're really small, they're about a quarter of an inch across at the most. A great many of them are a lot smaller than that. And they make their life living on the sea urchin, snipping off little pieces of spine and eating those and just generally kind of making life maybe a little bit miserable for these sea urchins. [*"We got the crabs."*]

But he was interested in those. Very few people had actually done any work on those, and he started studying them and he realized that people knew a lot more about crabs than they did about the hosts. And he started getting interested in sand dollars.

And anybody who has walked on a beach where sand dollars wash up knows that these things can wash up in huge numbers; some of them have holes right through them, some of them are extremely, extremely flat. And he began to wonder, what's the relationship between the holes and the flatness? And he got more interested in the hosts than he did in the crabs in the end. [*Alie laughs*]

I came along at around the time when he was switching his research program to all of this cool sand dollar stuff, and also fell in love with the sand dollars because there was a really interesting set of models about how they lived in their environments that were completely wrong. [*laughs*]

Alie: Really?!

Rich: Yes! There was a supposition that they walked around like little sieves to sieve the sand and get the particles out of the sand to feed on. And I started studying their functional morphology. I wasn't always an evolutionist, I was… Well, we're all always evolutionists. [*Alie laughs*] But I wasn't really studying what the relationships were amongst all the myriad different forms of sand dollars there might be. I was really interested in what's known as functional morphology, so that was a different -ology, I was a functional morphologist.

Aside: And functional morphology is all about asking, "Why does this part, do this?" It's the "why," while evolutionary biology is like the "who." And when Rich's mentor switched from crabs to echinoderms, Rich too was all aboard the echinology train. Like, toot-toot, in the functional morphology party car.

Rich: Particularly interested in the tube feet, which are tiny little cylindric, really extensible, really extendable tubes, fluid-filled tubes, that all sea urchins have, that they can use to extend out into the water or into the environment. And there's a sticky little pad on the end, some people call it a sucker, although we're not too sure how much sucking is involved. A lot of people think of them as little plungers or something like that. But they're very, very tiny on sand dollars, they're so small that they're very difficult to see with the naked eye and they're much less than the width of a human hair in some of the species.

But they're extremely dexterous, they can be very strong for their size, and they actually pick up the sand particles underneath the sand dollar and then pass them to the mouth along these grooves that you can see if you turn a sand dollar over. The mouth is in the center of this disc and the sand dollars are passing, using these tube feet, to pass the particles in the mouth. We found out that that was the true feeding mechanism.

But a lot of folks had suggested that the holes that you see in what are called keyhole sand dollars; these are things that you find in Florida and in some places, and actually along the Mexican coast to the south of California and all through the Gulf of Mexico and the Gulf of California, you find these animals that have holes punched right through their bodies.

Alie: How do they… Yeah, is one of them their butt? What's going on? [*laughs*]

Rich: No, well they do have butt, [*Alie laughs*] *but* that butt has a very special location on the flat bottom of a sand dollar. But these holes, there's variable number, but usually five or six of them. And they occur quite a long ways from wherever you would expect a butt opening to occur. They occur in the rays of the animal; they occur toward the edges. And the supposition was that they shorten the pathway of the food that was sieved on the top of the animal, to the mouth, but nothing could be further from the truth. Almost nothing goes down through those holes.

Alie: What are they for? Buoyancy?

Rich: Well, turns out, through the pioneering work of Malcolm, many years ago, that when you take these sand dollars and you put them in a wind tunnel, they have some very interesting properties.

Alie: Someone put them in a wind tunnel… [*laughs*]

Rich: They put them in a wind tunnel to simulate the flow of ocean currents over the body. And what he found out was that there was what they call an induced flow up through these holes.

Alie: Oh, wow, okay.

Rich: So, why the heck would they do that?

Alie: I don't know.

Rich: Well, if you look edge-on at a sand dollar, they have a very flat bottom and a curved top, and it should remind you of an airplane wing.

Alie: Right!

Rich: Curved surface, it turns out, induces the flow to accelerate. And when the flow accelerates, it experiences a drop in pressure. So, that's what keeps a 747 up, in part. And that's called lift. Sand dollars experience lift because when you look at them edge-on, they look a lot like an airplane wing. Lift is not so good for a sand dollar.

Alie: I was going to say, do they want to stay in one place?

Rich: They want to stay in one place, they're very, very picky about the types of sea bottom that they live on. And there are a whole lot of problems with just… The whole idea of lift and a sand dollar don't go well together. So, there are three different ways to counteract lift. One of them is to hold on. Unfortunately for the sand dollars, evolution has given them very, very small tube feet so there's not much to hold on to. And they live on sand so…

Alie: What do you grip anyway? [*laughs*]

Rich: What would they hold on to anyway?

Aside: So, Rich says the second way to counteract lift is just to be heavier. "Which is why we pay fees when we fly with heavy luggage," he says, and partly why sand dollar skeletons have a thicker rim along the edges, kind of like a crust on a toast. And that's called a peripheral ballast system. But evolution delivered a third option to this type of sand dollar and that option is called lunules. *Holey* smokes!

Rich: The third, and I think most interesting way, is to reduce this pressure differential between the bottom and the top. You can see that that's exactly what those holes are doing. It's kind of the same principle at work when anti-aircraft guns shoot holes through airplane wings, right? They don't stay up very well. And the sand dollar is actually exploiting that; equalization of pressure helps them stay in place.

Alie: Why do we find their skeletons on the beach? And is it lucky or not?

Rich: It's always lucky to find a sand dollar, [*both laugh*] I don't care where you are. But the main reason, certainly here in California – where we run into the ones on the beach here, almost literally run into them – they die, they pass away for a variety of different reasons, they reach the end of their lifespan, which nobody really knows exactly how long that is, but it can be probably a couple of decades.

Alie: Whaaat?!

Rich: Which is pretty old, for an invertebrate.

Alie: Yes! Yeah, for sure.

Rich: There are actually sea urchins that have been estimated to live over a century.

Alie: I can't– I don't believe you. I want a polygraph.

Aside: 100-year-old sea urchins, with some estimates going up to 200 years! This is a fact you will be telling people at dinner parties… well, for less than a century, because you don't live as long as a sea urchin.

Rich: As members of the big sea urchin family, sand dollars that are 20 years old probably aren't the oldest type of sea urchin that you would run across, so it's even more staggering than that. But if you get a storm, the sand dollars are scoured up, it doesn't matter how much they try to counteract the lift, they get dug out, basically, by the waves and they get washed up. Because sand dollars almost universally live in areas of what they call high hydrodynamic activity; there's a lot of currents flowing. There's a lot of currents being generated by wave backwash. [*"Surf's up."*]

So, these various adaptations are truly astounding. When I started realizing that these are really complex animals, in spite of their relatively simple appearance… I am nowhere close to finished with them. [*both laugh*]

Aside: And as far as their relatively simple appearance; the globe-shaped test of the sea urchin is just the skeleton. And just like that, any sand dollar that you find on the beach would look way different alive, not bony or stony or grayish white, but alive it would look darker black or purplish in color with skin over it. And underside, it looks like moving toothbrush bristles, it's so unsettling and very cool. And he could study these things for, like, 200 more years and still be curious. Which again, 200 years, the potential lifespan of a sea urchin. Wait, how does he know that? Do they have diaries? Do they write memoirs? I mean, molecularly, sort of.

Rich: The sea urchins that are a century or so old, those are estimates taken by… they make little growth rings in certain parts of the little plates that make up this test. By studying that and doing analytical work to try and figure out what those rings actually represent, and by doing experimental work in keeping these things in captivity, yeah, they can probably be 100 or more years old.

Alie: Do you ever eat uni?

Rich: I do.

Alie: You do! How do you feel about it? And what is uni?

Rich: Well, uni is a very nutritious substance that the sea urchins make. It's basically their gonads.

Alie: [*slow and croaky voice*] Reaaally?

Rich: Yeah. I've heard it referred to as roe, but roe is really just eggs. If you eat salmon roe or something like that, that's just the eggs from the salmon. You're not eating the whole gonad. But in sea urchins, you're actually eating the whole gonad, which is why it's okay to eat males as well as females; so, you're not throwing away half the catch. The sea urchin fishery in California is very heavily regulated in the south because the one that people really prefer, the big, fat red urchins that have big… big gonads.

Alie: Yeah! [*laughs*] To their own detriment, really.

Rich: Yeah, you know, size does sometimes matter. And in this case, it matters for the fishery. And people don't eat the purple ones quite so much. They're the common ones that you find in the shallower water along the shoreline here. But uni is a delicacy, it tastes really, really, really good. I mean, for those of us who… I don't know if you've tried it.

Alie: I've tried it, yeah. I was scared of it for a long time then I was like, "Oh this is really good."

Rich: Did you go back for seconds?

Alie: I did!

Rich: There you go.

Aside: If you have never seen fresh uni, it looks like a golden-colored tongue, it looks a lot like a cat tongue, but… but… gold. And it's kind of globby and buttery in texture and it tastes like when you pull up to the beach, and you open the car door and you say, "[*deep breath*] I am at the beach." It's salty, it's briny, it's the tiniest bit fishy, but mostly it just is like feeling wind on the shoreline. Kind of like if a crab and oyster brine collabed and launched a line of salty pudding.

And as famed uni enthusiast and chef Ali Bouzari described it to *The Splendid Table*, sea urchin gonads being really delicious to predators – which includes otters, and fish, and

humans like us – because sea urchin biology requires them to hang onto water in the salty ocean so:

> *They stockpile stuff that water likes to attach to. They stockpile sugars, amino acids, and salts, which is incredible for us, because those are maybe the three most delicious types of molecules in the edible world: sweet, salty, and umami. They basically brine themselves for us.*

And every time I eat uni I think, "Wow, it's so good, but it must be so bad for marine ecology." I'm fun.

Alie: And I always wondered, how are sea urchins doing population-wise? How are they doing? Because I see sand dollars and I think not a lot of people are hunting or it seems like are interested in a sand dollar alive. They're like, "You're dead. Your skeleton; it's going on my bookshelf." But sea urchins in general, do they reproduce slowly? How are they doing? And why… Yeah, I have so many questions.

Rich: It's like anything. If you think about birds, how are birds doing? Well, if you're a starling in North America, or any of a number of house sparrows, or whatever, they're probably doing pretty good. But there are other species that are doing pretty badly. The same is true for the sea urchins. I would say that the red urchin, which is a deeper water species, is probably doing fine. It's not in immediate danger of being overharvested. But there is a northern Atlantic species called *Echinus esculentus*.

Aside: And *esculentus* means edible. I had to look that up afterward, because contrary to assumption, I could not tell by the name.

Rich: And as you can tell from the name, it's a very well-known, very long-known species of urchin that was harvested for its uni for many, many, many, many years to the point where it's become threatened. So, that particular species is in a bit more trouble. There are several other species too that I would probably put on the threatened list because of the way they reproduce. They do reproduce slowly.

There's a brooding species that lives in the Caribbean that has become quite rare because its environment keeps getting disturbed. There's a conflict there because of nice, warm, lagoonal beaches, you know? And people like to use those for things that sea urchins don't really like very much. They're particular about the types of particles and things that they encounter in their environments. It's no different on these beaches where this particular species lives. So, I think its populations are hugely diminished.

There are actually laws in place in places like East Africa, along South Africa. There's an animal there called the pansy shell, which is actually a sand dollar. It's got two holes in it, and it's got an outline, a little but the shape of a pansy flower. When you look straight on a pansy flower, that's what you see when you look at the sand dollar. And a lot of people have collected those alive because they are also deep purple, so people like to collect those. Of course, they die… they get a little smelly.

Alie: [*sadly*] I bet.

Rich: And people don't think too much about a marine animal's feelings. So, they take them out of the water, and they die. There are now laws to protect those.

Aside: So, it depends on which species, and more on what kind of uni you should eat, in a bit. Also, broadly speaking, the spherical, globe-shaped urchins are regular echinoids, but sand dollars and sea biscuits – which look like cookies with a bunch of legs – those are less

symmetrical, and they're called irregular echinoids, which seems insulting, but honestly, I doubt a single sand dollar gives a shit what we call them.

Alie: Well, what about the sea urchin spikeys? What's going on? The opposite of a sand dollar.

Rich: Well, you asked me about the name. You started by asking me about the name. And the name echinoid comes from an ancient Latin word meaning spiney; *echin* or *echino* or *echinus*, any of the variants on that name, mean spikey. So, if you see that root somewhere, you know that it probably has something to do with spikes sticking out.

Alie: You're a spikey-ologist

Rich: I'm a spike-ologist! [*Alie laughs*] Yes, I am.

Alie: Why do they have all those spikes? And how hard is it, energetically, for them to make them?

Rich: Well, all the sea urchins are characterized by these spikes, and they are marvels of engineering. I would start out by saying that. Because they sit on a little ball-and-socket joint. So, the spine itself has a socket in the bottom of it that fits over this ball on the top of a sea urchin. Which is why, when you pick up a completely clean sea urchin, you see all these beautiful, smooth knobs and balls scattered all over it and it makes this beautiful geometric pattern. Some species are prized for that beauty and the aesthetic of having one of these on your coffee table.

Aside: So, each spine is on a ball socket. So, when you see an urchin skeleton, you now know why its evolution did such a knobby job.

Rich: But the spines themselves have a ring of muscle around that base, so that they can move forward, backward. They don't rotate on the socket, but they can swing around, kind of like stick shift in your car. So, you've got the ability to point this spine at anything that might be approaching. So, they use them for protection. Sea urchins that have the really big, long spines, like the black sea urchin of the tropics that a lot of people have run into... I don't know if you're a diver.

Alie: I'm not. [*"It's wet."*]

Rich: But there are lots of people who consider them kind of the scourge of the coral reef.

Alie: Oh really?

Rich: Yeah, because they have… they've made the mistake of bumping into one.

Alie: Right, they're the cactus of the sea, I see.

Rich: You have to be pretty careful. Yeah, it's like the cholla down in San Diego; [*Alie laughs*] you don't want to step on one of those. Sea urchins are actually… might in some ways be worse because they have this skin over them and when they pierce your body, that skin also goes with it and that can break down, bacteria get in there, and you can get an infection. So, they're kind of nasty.

A lot of people think that those are poisonous. But the truth of the matter is that the big, long spines on these black sea urchins are actually not poisonous, *but* they have a secret. If you manage, somehow, through your accidental brush up against a sea urchin to get to an even lower layer of spines, there's a set of shorter spines below that long set of spines that do have little poison glands in the tips.

Alie: Really?! How venomous are they?

Rich: They hurt like heck.

Alie: They do? Do they sting? Do they burn? Do they itch?

Rich: They sting. I would make it equivalent to a bee sting.

Alie: Oh! That's pretty hardcore.

Rich: Yeah, it's pretty hardcore and it lasts for a long time. I've been hit by some species during my expeditionary work and… Yeah, you feel it. [*"Just think about 60 bee stings, going right into your foot all at the same time and then leaving the stinger in your foot." "It hurts."*]

Aside: But Rich says that spines themselves can do different things. And sea urchins have gone through a whole bunch of evolutionary steps in diversifying the purpose of all those different spines.

Rich: So, when you look at a sea urchin, you're not just seeing a ball with spikes on it, you're actually seeing a highly evolved organism that has made the best out of the equipment that evolution handed it. And that ranges from poisonous spines, all the way to spines that look like umbrellas, spines that have no skin on them to encourage the growth of other organisms – clams, snails, barnacles, tube worms, and things like that – that disguise the smell of the sea urchin so that they're not bothered by predators. Because remember, they have that uni inside of them.

Alie: Oh, I know. I'm one of those predators.

Rich: Yes, and as much as we like that stuff, fish like it even more. [*both laugh*]

Alie: When it comes to the food web, whereabouts are they in the oceanic food web?

Rich: They're everywhere, actually. They're there as prey animals, but they are also top herbivores in a lot of different ecosystems. It's been demonstrated through study that if you remove, through overfishing, the top herbivore fish in a coral reef, the sea urchins explode in number because the amount of algae that the fish would be eating is now available for urchin growth.

Aside: Listen, man. Fish are away, algae is on tap, urchin party is raging. It's like "Untz, untz, spikes, gonads, poison. I got a mouth on my belly, a butt on the top." They got light sensors of 1,500 tube feet; they're like in a live Koosh ball. Shit gets crazy on a coral reef. It's a disco.

Rich: And the urchins will very rapidly become the top herbivore in a setting like that. So, they're not necessarily an indicator of a healthy coral reef but they do help on the coral's side of the battle in this constant battle between algae and coral. A little bit of algae is good but too much, like most things, can be detrimental to the growth of the coral. Urchins kind of fill that role of the herbivore fish in some of these environments today.

Aside: And as mentioned, they're all over the world. Now since Rich loves the phylogeny, the ancestry, and the relatedness of echinoids, how many different sea urchins are lurking out there for us to love on?

Rich: There are probably about 1,200 known species, but in the fossil record there's probably about 10 times that number. So, remember we've got a long time to look back, so you know… and those are just the ones that are fossilized and that we've discovered.

But some of the burrowing urchins help turn over the sediment in the bottom of the sea and do the same sorts of things as earth worms might do in your garden by turning over the sediment and turning over the soil. And they eat it as well, and through their feces, their

poops, contribute organic material to the sediment as well. So, they're pretty important just about everywhere you look in any given environment.

Alie: Can I ask you questions from listeners?

Rich: Sure, but I have to warn you; one question often leads to another.

Alie: Oh, I know! I know.

Rich: [*laughs*] And there's sometimes no simple answer.

Alie: The answer, "It depends," is probably the most popular answer.

Rich: It's my favorite one. It's my favorite answer.

Alie: [*laughs*] Oh my gosh. Yeah, we have so many…

Aside: Are you ready? Amazing. First though, we're going to scatter some money into the hands of science and people who need it. So, each episode we donate to a cause of the ologist's choosing. This week, we're sending it straight back to The California Academy of Sciences. I went there as a kid; it inspired my love for science. Also, Cal Academy is a really powerful voice for biodiversity research, exploration, environmental education, and sustainability across the globe. Thank you, Cal Academy, a donation went to them. So, here are words from sponsors that make giving from *Ologies* around the year, possible.

[*Ad break*]

Aside: And thank you to patrons who support the show and send in just the best questions ever, including a brainy one that was also asked by Christian Krupp and Jessica Cuddy.

Alie: Lee wants to know: Do sea urchins have a brain? And how do they walk with those spikes?

Rich: Well, that's actually two questions but let's start with the brain thing. Sea urchins do not have a brain. In fact, it's probably stretching the definition of a ganglion, to say that they have ganglia. They have little nerve clusters here and there, and there's a ring that kind of acts as a central processing unit, a ring of nerves that go around the esophagus, just inside the jaw apparatus. But sea urchins either have no brain at all, or they are all brain. Because there's nerve tissue underneath that skeleton everywhere, there's nerve tissue through all of the skin that covers all the spines and all the rest of the body. There's so much nerve tissue you can't help but think that if there's not thinking going on, at least there's some coordination.

We don't understand exactly how all of that coordination happens but it's pretty clear – and this gets to the second question – that there is coordination happening, because those nerve cells are talking to each other and telling each spine when it should swing, when it should move. In the sea urchins that have the really big tube feet, they're using those tube feet as well for locomotion and for holding themselves in place. So yes, that brain… it would be almost like if you could tell each individual hair which way to move on a given morning, you could have all kinds of new hairstyles.

Alie: Augh, I wish.

Rich: I would be seriously compromised [*Alie laughs*] but a lot of other, more hairy humans would have a great time with all of that hair. But yeah, basically the sea urchins can tell each of the spines which way to move. And I mentioned earlier that the spines can be pointed at things so they can actually sense pressure waves in the water. There's probably also some ability to sense the chemicals that fish give off and so the spines can point in the direction of an

attack, and they coordinate that as well. There's also some evidence that sea urchins can see.

Alie: I was going to ask! What's their sensory situation like?

Aside: Patrons who also wanted to know: Robin Kuehn, Alli Barg, Harper Thomas, and ALopez. And researchers found that we share about a third of a sea urchin's 23,000 genes. And Bronte-Maye wants to know: What is it like to be a sea urchin? What are they able to sense compared to humans?

Rich: It's mostly chemosensory, mostly by sensing chemicals in the sea water. They have a very sophisticated set of receptors for detecting different, for want of a better word, smells in the sea water. They can feel vibrations, they can use their tube feet to taste things and it's been shown that there's… Some of these nerves, that are spread all over the outside of the test, can actually sense light. And by the way, the light is falling on the spines, and on the tube feet, and on these different cells, they can actually form a rudimentary image.

Alie: No.

Rich: So, they can tell the difference between a large black spot on a white background or a small one. They seem to be able to tell the difference between a square and a circle. So, they are actually seeing things as well. And a lot of sea urchins respond to light.

Alie: Oh my gosh. Does that keep them in the right depth of water?

Rich: I'm not so sure it's about the depth, it's probably more about finding a place to hide.

Aside: So, sea urchins, they can be 200, like a wizard, they have a butt on their face, they taste with their spines, they see with their feet, and their whole body is a brain.

Rich: And a lot of them are very active at night. So, there are nocturnal urchins that come out as the sun goes down. They do feeding at that time, some of them reproduce at that time. Sea urchins, the sexes are separate; the males and females are separate, and the females will release eggs from their ovaries, the males will release the sperm from their testes, and the sperm and the eggs will mix in the sea water.

So, it's kind of a hit and miss, sort of unromantic situation [*Alie laughs*] that has to be kind of coordinated through group activities. They'll get together for this, or they'll release at a certain time when they can sense that somebody else upstream might have the right set of gametes for them. That's also done through chemosensory and maybe a little bit of tactile because some of the sea urchins do sidle up to one another and release eggs and sperm at the same time.

Alie: Which is very cute. I think that's very cute.

Rich: Which is very cute, of course.

Aside: You know what's not cute, well, depending on who you ask? Their teeth. Let's talk about it. First-time question-askers Emily Burke and Casey had questions, as did Lene Olszeth, Kimberly Hoffman, Natalie Gertz-Young, Gerald Thompson, maritime archaeologist Chanelle Zap, and Francesca Huggins, who asked with admirable frankness: What is up with the sea urchin's hellmouth?

Alie: Cassandra Grafstrom wants to know, or rather, demanded: Please talk about sea urchin TEETH?!? Which makes me wonder: is the thing in a sand dollar, when you rattle it around, is that a tooth? Separate question on accident.

Rich: Ahh, it's several teeth. If you have… Sand dollars, for example, have the doves of peace inside. People hear the legend of the sand dollar and one of the parts of the legend is that there are five doves of peace inside. Well, each of those five doves of peace is actually a jaw that holds a tooth.

Alie: [*Alie makes squirmy sounds, both laugh*] I love the idea of a disembodied jaw versus a dove of peace. Very different. [*laughs*]

Rich: Not quite the… You know, poets are amazing.

Alie: [*laughs*] Yeah, good work.

Rich: They do have such amazing imaginations. But sea urchins in general, not all sea urchins, and there's a remarkable group of sea urchins that do not have a jaw apparatus, but the vast majority of sea urchin species, particularly the globos ones with the big spines – and the sand dollars, as it turns out – have a five-part jaw apparatus. It's actually a very complicated structure. The general name for it is Aristotle's lantern.

Alie: Okay, casual.

Rich: So, I'm going to shed light on Aristotle's lantern for you. The lantern is kind of like the chuck of a drill, except instead of having three pieces that come together to hold the drill bit, there are five.

Alie: Oh, okay.

Aside: And just a little bit of etymological trivia: Aristotle described the urchin test as looking like a five-sided lantern but then that story just morphed into talking about the jaw parts. Also, just to say, I never knew the little claw part on a drill was called a chuck. Maybe we could call it Chuck's lantern… But yes, jaw parts.

Rich: And there's a set of very complicated muscles that open and close that chuck so that the teeth will come together and chew and retract again for the next bite. There's a set of muscles that allow the lantern to protrude out through the mouth to chew onto the sea bottom and they do that to chew on algae and things like that, and then pull it back in again. It can be rotated, swiveled a little bit to go in different directions once it is protruded. So, it's a really complicated thing.

The teeth themselves are set inside the five pieces of this chuck and they're a little bit harder than the rest of the skeleton, they have a higher magnesium content. Magnesium makes calcium carbonate, which is what the skeleton is made of. It's basically limestone but in a special form; it's tough and it's hard and resistant to cracking. But the teeth are really, really hard because of this magnesium content.

So, they will chew on the rock to remove algae for their food. But they wear out, so they're constantly being replaced at the other end. So, they're constantly being added to at the inside of the animal, and they move down this slide – it's actually called a tooth slide – very carefully and slowly over time as the business end wears out.

Alie: When, say, a sand dollar dies… Do the teeth… Are they smaller than the hole so they just kind of are out there, scattered?

Rich: Yeah, that's exactly what happens. So, if you look at the globo sea urchins, their mouth is really huge and so when one of those dies and falls apart, the test itself is loosely, more loosely held together so it falls apart. But one of the first things to happen is for the lantern to get lost through that big mouth. But in the sand dollars, the mouth is much smaller than

the lantern. But the teeth aren't, as you say. When the decomposition of the lantern happens, it falls apart into the doves, but the teeth themselves also fall out of those and just… usually they're lost out through the mouth by the time you find them on the beach.

Alie: Just lost at sea, a bunch of teeth.

Rich: Just lost, yup, lost teeth, please return to owner. [*Alie laughs*] Five teeth, they have to have five teeth, a full set. Orthodontistry is very expensive.

Alie: [*laughs*] I'd imagine. But luckily, it's fewer to brush.

Rich: It is fewer to brush. And you know, they're eating stuff that's good for them so… And heck, if they get a cavity, they just… keep growing.

Alie: Grow a new one. Hannah Roy wants to know: In your opinion, what is the coolest sea urchin? It's very important for them to know, thank you in advance.

Rich: It is very important to know what your coolest sea urchin is. And of course, every scientist will say, "Oh, they're all my favorites, I can't make a choice." But for me, there's probably… it's got to be the sand dollars. But that's a bit of a copout because it's a big group and, you know, there are close to 200 different species of sand dollars living today and they all exhibit weird structure. This is one of the reasons I like them for the study of evolutionary novelty. The holes themselves, that doesn't happen in all of the sand dollars, just a small subgroup. Let me see…

I've always been fascinated by the deep sea. And there are some, ironically, not sand dollars, but some sea urchins that live in the deepest parts of the ocean that are truly spectacular. And one of them, they don't have a common name.

Alie: Really?

Rich: No… Unless you want to call them fire urchins.

Alie: Fire urchins.

Rich: Yes, that's a shallow water representative of this group of about 60 species which are actually soft-bodied sea urchins.

Alie: What about their skeleton?

Rich: They have skeletons but they're loosely… all the plates… The skeleton of a sea urchin is made up of basically 20 different rows of plates, so there are 10 rows of paired plates. And those plates come apart when the animal dies because they're held together by connective tissue. But in these deep-sea ones, the ratio of connective tissue to skeletal pieces is really, really high. So, they're basically floppy things.

Aside: So, I dove into some video to gaze upon them. Because when a world renowned Echinologist says they've got a favorite specimen, you gotta look. And I was transfixed by video of what appeared to be a velvet beret, in stunning oranges, reds, and purples, but with spiked fringe across its lower rim. But don't let that elegance deceive you.

Rich: And you get these photos of these deep-sea urchins, and they look like sea urchins, they're nice and domed and rounded. They have probably the most toxic spines of any sea urchin. I've been hit only once or twice by those and I don't want to repeat the performance because it took probably about six hours for the pain to subside. It was like putting your finger in the electric socket.

Alie: Oh wow, where was this?

Rich: It was in Florida. It was actually on one of the submersible trips. And several of these fire urchins live in that area and when they're collected live and kept nice and cold like the deep sea is, they're still very much active… [*laughs*]

Alie: You could say that.

Rich: …and ready to do their thing. But there's very, very little known about what these animals are doing down in the deep ocean. They can live four miles down, maybe more.

Aside: Floppy creatures, named after fire, four miles under the sea.

Rich: And yet, they seem to be pretty common and it's hard to take a bottom photo without seeing one of these things. Certainly hard to go on any given submersible ride or expedition; they're doing a lot of these things with remote-operated vehicles now and on nearly every single dive, they're going to see some of these.

Alie: Well, how come it's your favorite if it did you so dirty? [*Rich laughs*] How come it's not your sworn enemy?

Rich: Because that sting represents the accumulated, brilliant activities of natural selection that has turned up an organism that just leads you to want to know more.

Alie: Spoken like a true functional morphologist psychologist indeed.

Rich: [*both laugh*] And their place in the evolutionary history of sea urchins is not very well known. At one time, they were thought to be primitive remnants of ancient sea urchins that we do know were probably fairly floppy-bodied. [*"Me too."*] So, back 300, 400 million years ago, most of the sea urchins living at the time were relatively soft-bodied. So, to see that in a modern group made everybody excited, "Oh, we've got the living fossil." But it's a representation of what we call a convergence in evolution. Different organisms will meet the same problem with a very similar answer. How many times has that problem been solved in very similar ways? And these soft-bodied… The technical name for these things is the Echinothurioida.

Alie: *Thuriidae*? What does *thuriidae* mean?

Rich: I don't know. The closest I've been able to get is "*thurus,"* which means ugly.

Alie: Augh! How dare?

Rich: But I don't think these things are ugly spiny things at all. I'm hoping that there's a different name, a different meaning for that word. But they're fantastic colors, they can also be very fast. Some of them have little hooves on the bottoms of the spines. You had somebody asking about spines. And there are little white hooves that keep them from sinking into the mud, and these things run across the sea bottom.

Alie: Oh my god.

Rich: They actually can move at…Well, for a sea urchin, at incredible speeds.

Alie: What is that? One mile an hour?

Rich: I would say several meters a minute.

Alie: That's pretty good.

Rich: Yeah, that's pretty good for a sea urchin.

Alie: That's pretty good for a little guy… for a Koosh ball.

Rich: Yeah, and these guys are not small. Some of them are at least the size of a basketball.

Alie: The size of a basketball! And they're called fire urchins?

Rich: Fire urchins, yes the *Echinothurioids*. There's only about 65 known species of them. But the other thing that is cool about them, there are structures that occur in between the spines that have jaws on them, and they're called pedicellariae. So, I'm a pedicellariologist as well. [*Alie laughs*] These are stalks that terminate in three… things like ice tongs.

Alie: Wow.

Rich: They can be also very poisonous, they can be used to clean the test, because it's very important to keep the skin clean. Some of them are used to scrape bacteria off, and interestingly enough, there are single-celled organisms that live inside, commensally inside the pedicellariae, they eat the bacteria so there's a whole system working there. There are other types of pedicellariae that do all kinds of different things and we don't even know what those are. The reasons for their differences in morphology haven't yet been fully understood. Why are they soft bodied?

Alie: I don't know.

Rich: I don't know either! [*Alie laughs*] Although there's a pretty good supposition that an animal that large is having a little trouble with getting enough calcium carbonate in the deep ocean. The reactions for extracting calcium carbonate from sea water to make your skeleton don't run very well in high-pressure areas.

Aside: So, these weak-bodied stunners, clearly his favorite genus and now yours, are the size of a dang basketball, they live under incredible pressure, they have more spines, like ice tong trident hands, and it's just too much to make bones in the cold, inky depths of the ocean, and they're going to hurt you about it. Which reminds me, a lot of you asked for advice in case you ever get smote by nature's pinhead hellraiser. So, here's some advice, since you asked, Rachel Murdock, Mackenzie Cyr, Kate Watters, Rose Scherer, Aven, Chaz Moore, Grace Robisheaux, Jules Kingsland, Jakin Yang, and E-Veh-Lease Sanchez.

So, according to the 2021 paper, "Sea urchin toxicity," you have to remove the spines ASAP, like you would an emergency splinter, because they can keep releasing venom even after they become disembodied. So, quick is good. That venom contains toxins and compounds with very scary names like glycosides and hemolysins, proteases, histamine, bradykinin; I don't even know what that is, but I don't want it in my foot. So, try to get them out. And soak the wounded area in hot water for about an hour, that might also help loosen them. You can take a Tylenol or ibuprofen if you need to. Make sure you have a tetanus shot and see a doctor if you start to see any signs of infection or if you're immunocompromised. And some Neosporin on the wound can help too.

If a dot remains, that might be pigment from the sea urchin's skin; which, side note to patrons who asked; Brittney Corrigan McElroy, Heidi Wright, Ren, Emma Luck, and first-time question-asker, Julie Miller. I spent a few hours trying to get a straight answer on why sea urchins can be such beautiful colors and the best answer I could find was online in a paper that said, "Ecological significance of color morphological variation remains unclear." Which I imagine was more frustrating to write for the researchers who studied it for three years than it was for us to hear it.

But if you have an animal embedded in your alive flesh, you don't need to pour candle wax on it, Alia Myers, who asked; or wait until the full moon to drizzle oil on it, like first-time

question-asker, Rachel Haslett asked about; or even take a whiz on your wounds, as much as you might want to, Amy Narimatsu, Brekk Bockrath, Ben W, Jesse Moses, and Jessie Dragon, most of whom likely saw the 2007 classic animated feature, *Surf's Up,* in which a penguin unleashes just a torrent of urine on another penguin. I don't want to ruin any penguin pee parties, but as you may know in your heart of hearts, birds do a buy-one-get-one on excretory hybrids. So, your first aid kit need not contain a penguin on diuretics, they don't even pee like that. But yes, there was a wonderful cameo by a fire urchin in that film. Fire urchins: you're witches, we love you. You know what, let's stay on them. A passion for fire urchins has been ignited.

Rich: Which I think dovetails nicely with the reason for why they have such virulent toxins in the spines, because if you don't have a hard test and stiff, big spines to protect yourself, you're going to resort to some other…you know… the nuclear option. [*Alie laughs*] You're going to go for toxins to help protect you from whatever fish predators there might be there.

Alie: Well, speaking of protection, a lot of people including Suzie Newby need to talk to you about hats; sea urchins and hats.

Rich: Hats! Oh, that's hilarious.

Alie: Do they really wear shells as hats or is that an internet lie?

Rich: It is not a lie.

Alie: [*gasps and whispers*] Amazing.

Rich: They don't do it nature.

Aside: And for anyone that missed this because they had a busy 2020, there was a post on Reddit that made all the internet rounds and it featured a home aquarist explaining that their pet urchins like to cover their domes, but the shells that they kept picking up were harming other critters in their aquarium so they 3D-printed these festive little hats for their urchins, which was visually a sight to behold.

And patrons Robert Foster, Harper Thomas, Quinn Newman, Adam Weaver, Ayshia Yaeger, Sikwani Dana, first-time question-asker Lizzy Carr, Dirty Donny, Matt Thompson, Mel Castellon, and Stephanie Broertjes, all asked and Suzie Newby, it is not a lie that sea urchins do this, but in the wild they are not so stylish, because…

Rich: Because there are very few 3D printers four miles down in the ocean. [*Alie laughs*] But they will pick up anything in the environment, some species – sand dollars, of course don't; they have different ways of protecting themselves – but there are some species, including some species that are named for that behavior, called collector urchins, that will use the tube feet to pick up things in the environment and wear them. [*"That looks amazing on you."*]

Alie: [*cutesy voice*] Augh, like a little hat?

Rich: Like a little hat. So, if you present them with nothing else than one of these 3D-printed hats, they'll wear it. They're styling, they look great.

Alie: Right now, as we sit here and talk about them, somewhere, there are possibly thousands of urchins out there wearing the clam shell like a fedora.

Rich: Absolutely.

Alie: God, that's a beautiful thought.

Rich: Yeah, long before there were fedoras, the sea urchins were wearing stuff. And they tend to do that to protect themselves, maybe from sunlight; because I mentioned earlier that they do react to light, so they might be protecting themselves a little bit from UV radiation in shallow water. But I think mostly, they do it to hide. I think mostly they are picking these things up, putting them on top so they're… Well, they don't have heads, but they're putting them over their upper surfaces to make it harder to detect them.

That works in two ways. One is, visually, you can't see them. For visually hunting predators like fish and things like that, it makes them harder to see. But I think they also use it because a lot of these things are actually still alive. Sea urchins will put pieces of algae on top of themselves, and of course, algae has a smell. So, they're masking their own scent. I mentioned earlier that there are types of sea urchins that encourage other organisms to grow on themselves. This is another way of solving the same problem, again; masking your own scent, by allowing others… So, you become a little ecosystem and you smell like that ecosystem instead of a sea urchin. The covering response though, it can extend to some pretty weird stuff; they'll pick up other dead sea urchins and put those on top.

Alie: Nooo.

Rich: Yeah, they'll wear those too. I have lots of photos of that.

Aside: So, an echinoderm is hiding from a killer by covering itself with its friend's corpse and it's just another Tuesday in the ocean. Also, I should note that their butthole is at the top so it's kind of wearing a hat that's also pants. Patron Jade Walker asked: Do the shells they put on interfere with their feeding? And Jade, again, butthole up top, mouth at the bottom.

But it's a great query and somehow it landed me an hour later, deep into a PDF of a study called, "Defecation behavior of the hairy urchin," during which I learned that yes, urchins poop from the crown of their not-head, but usually the tide and the water currents flush it away, just like an automatic toilet at the mall that sometimes flushes when you're still on it.

But on non-windy days, the urchins are like, "I'm no fool, this water's too still, I don't want this all over my eye feet." And researchers observed that these hairy urchins just casually tipped themselves over at about 30° angles to let the poop drop, because there's not enough current. And I love this information, and I hope these scientists' families appreciate the work that they have done as much as I do.

But that did not answer anything about the hat situation. So, I found the original Reddit thread, and nestled in the awe of the comments section was a nugget, from the original poster, VanillaBean5813, who said, "The funniest part is that they move the hats to the side so they can poop." [*DJ air*horn] But what street fashion has Rich observed?

Rich: Anything that's there. I've seen them wearing grocery lists that have fallen into the ocean, I've seen them wearing bits of plastic wrappers, even a coin.

Alie: Wow, that's stylin'. That's looking good.

Rich: Well, you know, they don't have pockets, but they can still carry the change. [*laughs*] [*"Keep the change."*] Evolutionary change, how about that?

Alie: [*Alie laughs*] When you see something like that, do you gently pick it off? Or do you say, "You're using this; I don't want to out you."

Rich: No, I usually don't out them, I'll take a photo. It's always good to have an urchinie, instead of a selfie, to remember.

Alie: An urchinie. [*laughs*] A spikie.

Rich: An echinie.

Alie: What about this biggest flimflam that you would like to debunk? What is a myth that you'd love to bust about a sea urchin or a sand dollar?

Rich: Oh, I wasn't anticipating that question because I'm debunking myths all the time, but it's usually coming from my fellow scientists. [*both laugh*] Let me see… A myth about sea urchins. Well, there is a myth… It's not so much a myth as an opinion; there are people out there that see urchins… see sea urchins… [*Alie laughs*] see/sea-squared urchins, as evil.

Alie: [*gasps*] How dare?

Rich: Well, yeah…that's kind of my response. There are people actively smashing sea urchins probably as we speak in places where the kelp forests have been severely harmed. Now, I understand why people feel that way. For a lot of people sea urchins are just a spikey nuisance. I would urge them to get to know them better. And the urchins that they're smashing are actually native species. So, if I need to go out and collect some sea urchins for my own research, I have to get permits out the wazoo, but there are people out there advocating for the wholesale destruction of a native species.

Again, I understand why. I understand the economic reasons for wanting to do this. It's very simple and that is that the urchins have chewed up and basically destroyed the kelp forests in which a lot of other organisms that people want to encounter, use, harvest, make their homes. And the sea urchins are vilified. I don't think it's upon us as humans to vilify anything in the first place, that's a natural product of millions of years of evolution. That's hubris that kind of goes beyond the pale. But I do think that there's a solution to this that goes a lot deeper than destroying the sea urchins. Not that we can harvest them and use them for uni.

There are people who have said, "Oh these purple urchins…" not the red ones, but the purple ones that are the most visible culprits, if you will, in the destruction of the kelp forests, by chewing them down… "Those purple urchins are hunting down the last vestiges of what was a once plentiful algal resource." The kelp forests were once in good shape, and the real culprits in this are the people who have made it hard for kelp forests to regenerate over time by removing the top predators of the urchins, by changing the climate, by doing all of the things that pollutants, things that kelp can't tolerate, to build these magnificent ecosystems that once existed in huge abundance up and down the coast. So, the vilification of the urchins in this picture is, I think, a little bit misplaced.

Aside: And scientists have found that although kelp is one of the fastest growing organisms on Earth, it just can't compete with the purple urchin explosion, which has grown 10,000% according to Oregon Department of Fish and Wildlife scientists, which blame, rightfully, warming oceans and a drop in starfish, plus a huge sea otter decline due to toxic runoff and rabid hunting in the early 1900s.

So, if you're in an area with rapidly declining kelp forests – like California, hello – belly up to some free uni, it's almost free. A fishing license is less than 50 bucks a year, and you can grab up to 35 purple urchins… per day. 35 a day is the limit; that's how many are out there. And in some areas with the worst kelp reduction, there's no limit to hand harvesting.

Speaking of hand harvesting, wear gloves. So, enjoy the uni if it's purple urchin, and don't blame the urchins, they are just making the best out of a situation that we made bad.

Alie: And you know, I was going to ask, I always ask, the hardest part about your job? I imagine that must be difficult. Is there anything annoying about being an echin– echino– … Help me out.

Rich: Echinologist.

Alie: Echinologist. Is it the spikes? Is it being in submersibles if you have claustrophobia? Is it emails? What's the one thing that you're like, "I love this job, but I hate this part of the job"?

Rich: [*laughs*] Well I don't think there's… Well, there are very few scientists of which I'm aware that like going to meetings. [*Alie laughs*] But I also think that in all of the things that we don't like doing, there are occasional opportunities and gems of moments when the importance of what you're doing can really take hold.

So, it can be in the form of talking to people like yourself; doing a public outreach in the Philippines to talk to people about the importance of coral reefs; to reach out and talk to someone who is with a funding agency to show that the work that we do on a daily basis in a museum setting like this – surrounded by the wonders of nature, represented in the collections here – that this is a resource that helps us to understand the place all of these organisms in this interconnected planet… You can't do anything on this planet, without touching one of the things that we make it a point to study every day of our lives.

So, for me to complain about any aspect of being able to do a job that I've dreamt of doing since I was 9 years old, would be… That's a crime of some sort. [*both laugh*]

Alie: I love– This is maybe the first pass I've ever had on that, which is beautiful. But what about your favorite thing?

Rich: My favorite thing is probably… making a discovery. And it can be a discovery of any type. It can be tiny, or it can be huge. But making a discovery about the interconnectedness of life on the planet… I'll give you a good example. I was really happy to be able to help lead an expedition in 2011 to the Philippines, and one of the components of that expedition was a deep-sea dredging expedition; where we set records for the depth off of the Philippines where we dredged; made discoveries of all kinds in this environment.

And on one of the dredge hauls, there was a piece of wood, and on that piece of wood, was a tiny, little white sea urchin, no bigger than your pinky nail. Well, your pinky nail is pretty big but [*both laugh*] small, very, very small. Inconspicuous. Didn't give it much of a thought at the time except to wonder what the heck it was. Until I discovered some months later that this was a member of a group of sea urchins that specializes in eating wood… in the deep sea… a mile down!

Alie: Whaaaaat? Did they evolve since shipwrecks are off of the coast of places where it's brackish?

Rich: Oh no, they evolved long before there were shipwrecks. [*Alie laughs*] Just the same way as shipworms didn't evolve when there were ships, they were around a lot longer. What happens is, in the forests of the Philippines you have tree falls; they fall into the rivers, they wash down the river, they slide out into the ocean at the deltas of these rivers, they float out at the surface for a while, then they become, literally, waterlogged. The logs will sink, and these sea urchins find them and settle on them, and they are symbiotic with microorganisms that help break down the cellulose in the wood.

Alie: Wow. [*"Very…very specific."*]

Rich: Kind of like termites. And that's how they make their living. So, for every type of organism, there is a specialty, and these sea urchins specialize in eating wood. And what each log represents is this huge injection of food energy, it's almost like a stepping stone to these incredible whale fall communities that you read about… A whale dies and becomes the center of action for… Becomes the world's biggest Safeway for all kinds of worms and things like this. And these sea urchins are doing the same thing, and they're probably living for a long time. Nobody knows how they find this stuff; nobody knows how they find the wood; nobody knows how they reproduce in such a way that their larvae can live long enough until they find a piece of wood. The mysteries go on and on. But all I can tell you is that this connection between a mountain forest in the Philippines and a deep-sea community two miles down, just fills me with awe.

Alie: Augh. That's amazing… *Wood* you believe it?

Rich: Wood you believe it? [*both laugh*] You do have to *branch* out a little bit in studying these things but…

Alie: [*laughs*] I gotta *leave* this one alone. [*both laugh*] And I love that, like that urchin; there's a few of you that do something very specialized and you're just perfect for the job.

Rich: Well… I shudder to think sometimes about how many opportunities have been lost to make a discovery because you didn't have the right person at the right moment. Being prepared helps a lot, and so we populated the expedition with people who were likely to make those sorts of discoveries. And I think we need to keep doing that. Places like this where the guy next door is an expert on food webs; or the guy two doors down is an expert on coral distribution and reproduction; the person three doors down knows everything there is to know about soft corals; and the guy beyond that knows everything there is to know about nudibranchs.

So, when you put a team like that together and throw them out in the field, it's incredible the synergies that can grow out of that. I once found a small sand dollar that had picked out of the sediment some weird star-shaped things that were about large sand grain size, and I didn't know what they were but the person sitting next to me happened to know that it was a species of *foraminifera* – it's a single celled, almost like an amoeba with a shell – that lived in the sand. And it lived in large enough numbers that this species of sand dollar had specialized in feeding only on those.

Alie: Unbelievable.

Rich: I would never have known that. I might have cleaned that stuff off to make the specimen nice, but she was able to tell me, "Hey, wait a minute, that's interesting." That is one of the delights of the work that I do. I will not have regrets as long as I can work with people and organisms that never let me down when it comes to something cool.

Alie: Well, I hope there's more echinologists out there…

Rich: Echinologists… Well, I hope there are now.

Alie: … that are coming up too.

Rich: Yeah, get out there, start drawing your deep-sea research vessel.

So, ask aquatic people some fire-y questions. And you can follow The California Academy of Arts and Sciences on Twitter, I love them, and on Instagram they're @CalAcademy. We are @Ologies on

Twitter and Instagram. I'm on both @AlieWard. You can say hi, show us your *Ologies* merch, say hello to my dog.

There are links to a bunch of stuff we talked about and more info on the wonderful Rich Mooi is at the link in the show notes, it's AlieWard.com/Ologies/Echinology. Hello to the *Ologies* subreddit and the *Ologies* Podcast Facebook group, which is adminned by Erin Talbert. Thank you to Shannon and Boni from the podcast *You Are That* for helping with the adminning.

Thank you to everyone at Patreon.com/Ologies who supports the show always. Susan Hale works on so much behind the scenes, as does Noel Dilworth. Emily White of The Wordary makes our professional transcripts and Caleb Patton bleeps them. Those are available for free at AlieWard.com/Ologies/Extras.

Zeke Rodrigues Thomas of Mindjam Media heads up the *Smologies* efforts and those are truncated and de-filthed episodes that come out every few weeks; they are suitable for all ages; Steven Ray Morris helps with those. Kelly Dwyer manages the website; she can build you one too. And big thanks to lead editor and best-dressed butt, Jarrett Sleeper of Mindjam Media. Nick Thorburn made the *Ologies* theme song who… He also made *Serial*'s. Isn't that nuts? He's in a band called Islands, great band.

Anyway, if you listen to the end of the episode, I tell you a secret and great news! I did not seem to have contracted COVID. It appears that my immune system and three shots put on a good fight. And two rapid tests and a PCR later, I'm negative. So, I'm all clear to go see my folks this week again. And thank you all for all the warm wishes and the good vibes, it's really appreciated. It just is. It's just really nice of you. And thanks *Innovation Nation* for letting me take a leave of absence in order to be present where it matters most.

And another fun fact, we put up an owl box in the yard today… So, please tell the barn owls of LA to report to my yard so I can admire them. Okay, give yourself a hug, take it easy. Berbye.

Okay, I'm doooone.

> [*Easter egg clips from various sources*]
>
> *"Looks like you stepped on a fire urchin."*
>
> *"Stepped on me, stepped on me. Are you kidding? This guy was dancing on me, I mean look at this… broken, broken, gone, gone, broken, broken, broken."*
>
> *"This is… this is pretty bad*."

And just as a little bonus if you wanted to stick around and hear my thoughts about electric vehicles and some knowledge exchanged, I had a discussion with a few guys from *StarTalk* about electric vehicles. Here we go.

Heyyy, *StarTalk* fans, this next segment of our episode with *Ologies* host Alie Ward is sponsored by the all-electric Chevrolet Bolt EUV, the everyday electric vehicle for everyday people… that's you. The all-electric Chevy Bolt EUV has so many cool features including the ability to engage in conversations hands-free with the industry's first hands-free driving assistance technology. You can find out more at Chevrolet.com/Electric/Bolt-EUV. Alright, let's get back to the show.

Neil: We're back, *StarTalk: Cosmic Queries*, and for this segment we're going to actually devote this to a discussion about electric cars. Chuck, what do you think of that?

Chuck: Yes, that's awesome because I know you don't like the word "awesome" but in this case, I think it is awe-inspiring.

Neil: Just to be clear, I love the word "awesome" but when properly applied, like when you discover a new universe or something. [*laughs*] When people say, "It would be awesome if you could pass the salt," that is not a good use of the word awesome, okay? Just to be clear.

Chuck: Okay, here is a good use of the word awesome because electric vehicles actually do so much to help the environment. I care about the environment, I know you do, people don't think I do, but this segment, we're doing in partnership with the Chevrolet Bolt EUV. So, I'm just over the moon because we get to talk about electric vehicles man, and that's our future.

Neil: So, is EUV; is that like SUV except electric? Is that how we're going to…

Chuck: Yeah, man! Doesn't it sound better though? Doesn't it sound better to be like, "EUV"?

Neil: EUV… Ooo… Let's get back to our guest here, Alie Ward from *Ologies*.

Alie: That's me.

Neil: Basically, did a land grab on all -ologies in the universe. [*Alie and Neil laugh*]

Alie: All of 'em! [*laughs*]

Chuck: That's a straight power move.

Neil: That's a totally gangster right there, it's like… if it's an -ology…

Alie: Once you get that handle, you're sitting on it and it's yours. But yeah, this would be electric vehicle technology, I suppose, this segment.

Neil: The -ology, okay? You just cram the ology in, whether or not it belongs. [*laughs*]

Alie: Yes, that's what I do. Someone mentions something in casual conversation, and I tell you what -ology it is. But this one is really exciting to me. I've been excited about electric vehicles since I was a kid. My dad is really into alternative sources of power and solar power. So, I have been watching for years and seeing how EVs come on the market. So, I'm really excited about the Chevrolet Bolt EUV. I think EUV is a good name too, I like the way it sounds.

Neil: Cool, and Chuck… But is it, like, $100 grand like other electric vehicles? What's going on there?

Chuck: That's the great thing about it.

Neil: Otherwise, it's not for everybody. You can't take that Chevy to the levy if it costs that much. [*Neil and Chuck laugh*] No good ole boys are doing that. So, what's the price point on this?

Chuck: That's why they drained the levy, is to pay for your very expensive… Which this is not. Actually, when I said it's accessible, that's what I mean. It's you know, this is a car that allows people to enter into this realm and if you're a conscientious person...

Neil: As a first foray. Okay, very good, very good. So Alie, do you have a question?

Alie: I do actually. I wanted to know…

Neil: Wait, wait, wait. Actually, that's not fair because you're our guest and we usually take questions from the audience, from our fanbase. But you know, you seem so into it, maybe we'll give you the occasion to ask the question, with the permission of our fanbase, I think they'll allow it.

Alie: Okay, so the floor is mine, I have the *Cosmic Query* conch right now and can launch a question. So, I wanted to talk about whether or not electric vehicles are good for the environment. How much good do they do over a car that runs on fossil fuels? What are your thoughts on that?

Neil: Oh, yeah, yeah. So, I don't claim to be the world's expert on that, but I can get you a lot of the way toward an answer to that question. So, here is the problem: transportation today, you know, cars and trucks and things that move commerce… I guess even trains, but some trains are electric, so let's just stick to the ones that have engines that burn fossil fuels. The problem is, if you have a car that takes gasoline, it can only run on gasoline, right? So, if you run out of gas, you gotta go to a gas station and fill it up with gasoline. So, you know, we all know how much gas costs and we know where it comes from in the world, we know if a pipeline gets shut down, or we know if a war breaks out, we know if an oil well is on fire, and we know if there's new regulation related to it. So, oil has become a strategic commodity, simply because we need it to run our transportation grid.

So now, in comes an electric car. So, an electric car, of course it still uses power. So, what's up with that? Why is it good rather than neutral, or bad, or equal? So, here's what happens: you got your car, it's at home, and you plug it in. Now, it's getting electricity from your power plant. There's a chance your power plant is using coal, there's a good chance of that. So, that's not really much better. All right, burning coal and burning gasoline, there's still this carbon footprint. Okay.

However, the power plant is not limited to just coal. If they wanted to, and many have, they can put in – if they have sunlight where you are – a solar farm or a wind farm; if you're near water, you could be hydroelectric. All of these sources of power can be generated by your power company and show up in your wall socket. So, you don't need 12 different engines in your car to use 12 different types of energy, you just need a plug that gives you access to the thing that's generating the energy 12 different ways. So, if you electrify the transportation grid, you are future-proofing our path into a culture and a civilization that can wean itself off its dependance of fossil fuels. So that's why it works, that's why it's good.

Alie: I like that answer. Not to mention, if you go solar on your house you essentially have a solar-powered car, which is a car powered by the sun.

Neil: Ohhh yeah! Exactly.

Chuck: There you go.

Alie: There's gotta be a bumper sticker for that, like "Solar powered vehicle."

Neil: [*laughs*] Yeah, but that wouldn't work in places like Seattle where the sun never comes out, or upstate New York. But yeah, it would be believable if it's in a place where the sun is prevalent. So, that's why electric is good.

Now, the problem is I can have a gallon of gas over here and I can move it over there where you need it, okay? You can't carry electricity with you. Sorry, you can charge a battery, and then I can move the battery over there… No, the battery is in the car. So, one of the problems with electricity as it's generated is, it can only… You can't sort of store it outside of the battery that's in your car. So, to run your lights, to run most of the things that civilization uses electricity for, it doesn't come out of a storage battery, it's generated on the fly as you need it, from the power station and delivered by the high-tension lines.

Chuck: I was going to say, I'm glad you said that because there's a lot of people who are electric vehicle hesitant, I will say, because they're worried about how far they can drive because of what you just said. And the cool thing about the industry, but more importantly about the Chevy Bolt EUV – I know this because I got to take a tour of the car with GM – the cool thing is this car has nearly 250-mile range on a full charge.

Alie: 250? That's good.

Neil: That'll get you between any adjacent cities. I mean, New York City is 250 between Boston and Washington. And you're in LA, Alie? What cities…? San Diego.

Alie: Oh, if you need to make a getaway, that's Palm Springs, that's Joshua Tree, that's Santa Barbara, that's… Yeah, up the coast.

Neil: Excuse me, Joshua Tree, oh excuse me, okay… different hangouts.

Chuck: [*fancy voice*] Excuse me, I'm about to take my Chevrolet Bolt EUV down to the Joshua Tree. Mmm, perhaps you'd like to meet me there. [*Neil laughs*]

Alie: Sometimes you need an Instagram shoot and you need to get in your Bolt. I love the EUV. If you like a hatchback with a little bit higher profile… yeah, I love that. And the range is great. They call it range anxiety; people who are afraid to go EV because they think they're going to be stranded. But once you drive an electric, it's kind of like once you become a birdwatcher, you start seeing all these charging stations, just like you would see birds you didn't realize were there before. Once you drive an EV it's like, "Oh there's a charger everywhere." They're everywhere, you can charge in parking lots at the mall, you can charge next to your grocery store, you can charge at hotels, it's just like… it's really easy.

Neil: Okay, so the bird-watcher analog there is; if you've never looked for a bird, you would never know it was there until you knew what to look for. And then they're everywhere. I gotcha, okay. So, that's just like a psychological effect.

Alie: Sort of, once you know what to look for. But yeah, there's EV charging stations everywhere.

Chuck: Yeah, there's about 40,000 birds to look for when you're traveling.

Alie: Is that how many EV stations are there?

Chuck: Yeah, there's about 40,000 public charging stations.

Neil: So, Chuck, which goes faster down the road, a Chevy Bolt or Usain Bolt?

Chuck: You know, I'm going to say that the Usain Bolt is faster out of the blocks, but the Chevy Bolt is going to ultimately smoke him. [*Neil and Chuck laugh*]

Neil: Don't tell him that.

Alie: Not to mention, you don't need as many carbs for your Chevy Bolt, you don't have to run it on pasta, protein, anything. I think range, better range.

Neil: Oh, I gotcha. There you go. So, is that the only question you had, Alie?

Alie: Well, that was my main question about it. I think people who are considering going from a fossil fuel car to something that is electric, I think tend to be people who are environmentally conscious, so they really want to know, how much better is this for the environment? But knowing that you can use…

Neil: I agree. And those are the people who do it first but ultimately, if you get the right price point, people just do it because it's the right price point.

Chuck: Wait, so speaking of what you just said, before we actually got on this show today, Alie was doing something on your computer where you were looking at the savings… So, when you talked about price point, there are hidden savings in every electric vehicle but I don't know… What were you doing?

Neil: Well, there are fewer moving parts. Can I back up real quick? We're running out of time; I don't want to take up the whole thing. But Michael Faraday, go back 150-60 years.

Chuck: When you said back, I thought you meant back in the show. [*all laugh*] Like, "Can I go back? Michael Faraday…"

Neil: So, Michael Faraday – an English scientist, physicist – he basically is responsible for figuring out how to generate electricity and he invented the concept of an electric field, by the way, because that's not a thing you can touch, it's just this thing there. He can draw it; you can calculate with it. He realized that if you move a wire through a magnetic field, it induces current in that wire and it'll show up on a meter.

So, woah, it was a little novel at the time, what would you do with this? This is kind of a stupid toy, and then people figured out, "Oh my gosh, this is the birth of the electrification of the world." Point is, the way we do that now is we have a tightly wound – in what's called a turbine – a tightly wound wire coil that spins in a magnetic field and an electric current is induced in that wire. Ever since the beginning of electricity, we've known how to spin things…that's what we do best, we've been doing it for 150 years. And what is a car if not electricity spinning things? So, the acceleration on an electric vehicle can be excellent because of this fact. The Chevy Bolt, I didn't check the acceleration numbers, they might actually accelerate out of the blocks faster than Usain Bolt, now that I'm thinking about it.

Alie: Also, I was checking on price point stuff just to see how much would I save per year driving an EV? And my parents live about 400 miles away so I go up a couple times, obviously, every month or two. And I would save $10,000 over 5 years on gas, just based on that. Which is, yeah, if you're calculating how much…

Neil: Not to mention how much CO2 that is.

Alie: I know. So, a little karmically and then pocketbook-wise. But yeah, they have a number cruncher for you, so you don't have to pull out your spreadsheets. They have it for you. And yeah, the acceleration is better.

Neil: I see what you did when you said *car*-ma… karmically. I see what you did there.

Alie: You like that? Electric, the puns are electric.

Neil: [*laughs*] So guys, we gotta land this plane, or park this car. [*all laugh*] So Alie, it's been a delight to have you on the show. I can't believe we've never done this before. We gotta do this again, with your permission, and talk about some of the -ologies that you've discovered… Or I think you're inventing some -ologies?

Alie: Mayyybe bending some words.

Neil: I think you're pulling them out of I don't know where. [*laughs*]

Alie: I swear, I do look for them in literature first, I promise. But yes, so many -ologies to cover, I'm here whenever you need me.

Neil: And so little time, yes. Excellent. Thank you for being on *StarTalk.* And you can catch her on her *Ologies* podcast. It goes everywhere, every -ology you could ever imagine, even the ones you haven't imagined because she made them up, they're there. [*laughs*] Chuck, always good to have you, man.

Chuck: Hey Neil, before we wrap up, I just want to let the viewer know that if you're ready to make the electric future part of your present, do some good for the environment which is what it is all about, check out the Chevrolet Bolt EUV and Chevrolet.com/Electric. Do some good people, come on.

Neil: All right, this has been *StarTalk: Cosmic Queries*, Neil DeGrasse Tyson here, as always.

Transcribed by Aveline Malek at TheWordary.com

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