

"CREATURES OF THE DEEP"
SHOW 604

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EPISODE OPEN

ALAN ALDA On her back like this, this tiger shark's in a hypnotic trance. When she wakes up, she'll lead us on a chase through the Hawaiian Islands.

ALAN ALDA (NARRATION) We'll also dive deep into an unknown and alien world. Learn by touch alone...

ALAN ALDA Yoo hoo. Lunch!

ALAN ALDA ...of an ancient arms race. Meet a very smart octopus...

ALAN ALDA Look, he got in. He got it open.

ALAN ALDA And see how an ear...

DARLEEN KETTEN It's gigantic.

ALAN ALDA ...keeps whales out of trouble

ALAN ALDA I'm Alan Alda. Join me and the Creatures of the Deep on Scientific American Frontiers.

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SHARK TRACKERS

ALAN ALDA What do you think? Are we there yet?

BOAT CAPTAIN Yeah, we are just about to the canyon now.

ALAN ALDA We're less than 10 miles off shore from Monterey California. We're just coming up to a place called the Monterey Submarine Canyon. Which until recently was almost completely unexplored. I'm going downstairs.

BOAT CAPTAIN Take care.

ALAN ALDA It is sometimes said that we are less familiar with the Earth's oceans than we are with the surface of the moon. There is a lot of truth to that. When this research team started studying the Monterey Canyon 6 years ago, they immediately began discovering strange new creatures that were completely unknown to science. We are going to take a look down there in the canyon and who knows, we might discover a new species. First, we are heading 2000 miles across the Pacific to meet a more familiar, but much scarier kind of creature.

ALAN ALDA (NARRATION) The balmy waters of Hawaii. Tourists by the tens of thousands splash in these waves every year - while just below them glide hundreds, perhaps thousands, of the deadliest killers in the ocean. Every now and then, shark and human meet.

NEWS BROADCAST This morning a BYU student was attacked by a shark while surfing.

ALAN ALDA (NARRATION) As predictable as the breathless media coverage are calls for shark control programs that would literally fish the killers out of Hawaii's coastal waters. Which is why this University of Hawaii research vessel regularly sets out from Honolulu harbor.

KIM HOLLAND You can actually dictate the size of the shark you catch by the size of the bait you use. So a good big tuna, nice and bloody, just what we need.

ALAN ALDA (NARRATION) Kim Holland and a team of graduate students are baiting lines to catch tiger sharks - the species that poses the greatest threat to Hawaii's humans.

KIM HOLLAND That's a tasty morsel.

ALAN ALDA (NARRATION) But the team isn't fishing for sharks in order to control them. They're on a research mission to find out if tiger sharks can be controlled - and what the consequences of killing them might be. The baited hooks are left out overnight. When morning comes, the research crew gets an extra hand for the day.

KIM HOLLAND Okay, Alan, do it. Oh man, you've done this before.

ALAN ALDA (NARRATION) As we headed for the first line of hooks, I asked a question I've always wanted the answer to.

ALAN ALDA Is there any evidence at all that there is such a thing as a killer shark, a shark that goes after humans?

KIM HOLLAND No, in terms of the tiger sharks and as far as I know with other species of sharks, there is no evidence of that what so ever. And when you think about it, sharks evolved in the ocean, man did not evolve in the ocean. If they have evolved eating man, or mankind, they wouldn't have gotten very far, because until the tourist industry hit there wasn't very many people in the water. You can't make a living eating something that is not in your realm.

ALAN ALDA What about if a shark bites a human?

KIM HOLLAND Which doesn't happen very often.

ALAN ALDA Right, how often does it happen?

KIM HOLLAND In the state of Hawaii, it only happens maybe twice a year. And when you think of how many people that are in the water all year round, and how many sharks there are...

ALAN ALDA How many sharks are there?

KIM HOLLAND There are a lot of sharks, because we catch sharks all the time. There is no problem.

ALAN ALDA So, the interesting thing is, with all of those sharks there are only 1 or 2 bites a year.

KIM HOLLAND Right.

ALAN ALDA Now, how many of those bites are fatal?

KIM HOLLAND Good point. Very, very few. In Hawaii in the last 30 years, only 3 attacks have been fatal.

ALAN ALDA (NARRATION) All that didn't sound so bad. And the first shark we hauled in looked reassuringly harmless - especially when Kim rolled it onto it's back.

KIM HOLLAND If you turn it over like this, these fish go into what we know as tonic immobility. So, even if this fish wasn't very tired, it would basically go to sleep in this position.

ALAN ALDA (NARRATION) It was a 5 foot long sandbar shark - not a species much given to biting humans.

KIM HOLLAND What Carl is going to try to do now very carefully, is take the hook out of her mouth. Well done, mate. And then we are going to let her go.

ALAN ALDA Is there any relationship between these smaller sharks and the tiger sharks?

KIM HOLLAND One of the few things we do know about tiger sharks is that one of their main foods is smaller sharks. So, if you kill the large sharks, the number of medium and small sharks will probably increase. Their food is frequently the commercially important fishes. So, by affecting the top predator, you may end up perturbing the ecosystem such that the commercially valuable fish will decrease in numbers.

ALAN ALDA (NARRATION) So trying to rid Hawaiian waters of tiger sharks could reduce the populations of fish Hawaii and it's tourists like to eat. It was beginning to sound as if tiger sharks don't deserve their reputation. Of course, I'd yet to meet one.

KIM HOLLAND Okay. We got a tiger shark on this line.

ALAN ALDA Good.

KIM HOLLAND It's alive, and it's a medium size one. Here it comes right now in the water behind us. Well, that's a big one.

ALAN ALDA How long do you think he is?

KIM HOLLAND That is about a 13 foot long shark.

ALAN ALDA 13 feet. And would you say he's tired?

KIM HOLLAND He's just the way we like him. He is still obviously very healthy, but very tired so we can work with him. Put a transmitter on him and let him go. He's safe, we're safe, we get what we need. He's just the way we like him.

ALAN ALDA Let me ask you a serious question here. When the shark has that hook in it's mouth? Is it just as able to bite as without the hook?

KIM HOLLAND No. And the other thing you have to realize is that sharks don't use their mouths for defense or for aggression. Their mouths are for feeding. So, it's not like a dog that is cornered and strikes out to you with his mouth. These animals don't think about taking their vengeance out, or being so frightened they come and bite you. All this shark wants to do is get that hook out of his mouth and go about his business.

ALAN ALDA (NARRATION) And it was finally time to go about our business - which was to tag the tiger shark with a radio transmitter so that we could track it. Killing the tiger sharks around Hawaii's beaches would control the threat they pose only if they don't travel very far. And until this research project, no-one has known how far tiger sharks roam. It was time to meet the tiger face to face.

ALAN ALDA It's a gigantic head on this shark.

KIM HOLLAND Yes, it's like a big tadpole.

ALAN ALDA It's doing what? It's biting the boat. That doesn't sound like what you said before about not biting people that aren't food.

KIM HOLLAND That's the great thing about science, it's the world of discovery.

ALAN ALDA (NARRATION) Like the little sandbar shark, this one was supposed to go into a trance when belly up.

ALAN ALDA You had her over on her belly, how long do you have to keep her on her belly for this effect to take place?

KIM HOLLAND It varies, but usually just 3 or 4 minutes and she'll go quiet.

ALAN ALDA Oh, 3 or 4 minutes? Oh, I thought it was a couple of seconds.

KIM HOLLAND No, well, it depends, sometimes it can be. There she's going now. Okay, see, there, she is gone now. As long as we can keep her belly up she will be alright. Look at that. Rub her tummy.

ALAN ALDA Does it make any difference if you rub her tummy? I mean, does that help her quiet down?

KIM HOLLAND I don't know. But you know, it's a very , very calming phenomenon in all vertebrates that...

ALAN ALDA Oh gee... Oh boy... That's why I'm, I'm playing the part of Richard Dryfus. What, was he busy today?

KIM HOLLAND And if you like to...after Brad makes this initial incision here like that...; you're welcome to put it on if you like.

ALAN ALDA (NARRATION) After they'd made the shark really mad by sticking a knife in her skin, I got the privilege of implanting the radio transmitter.

ALAN ALDA All right. Here's the transmitter. What do we do with this?

KIM HOLLAND We are gonna put it right in the incision on the back of the shark. Right here where we made this small incision. Right there. That's it, right in that hole. Right there. Push. Beautiful. Give it a not, one more not, there you go, a little bit more, perfect. There it is right there. There is the transmitter in place, we can follow her wherever she goes. Because it's a depth sensitive transmitter, we not only know where she is going sideways, but how deep she is, whether she is near the surface, near the bottom, 10 meters or 100 meters deep. That's perfect, you should do this for a living.

ALAN ALDA Ha, Ha.

KIM HOLLAND All right.

ALAN ALDA No, I shouldn't even do this for a living.

KIM HOLLAND Ha, Ha.

ALAN ALDA (NARRATION) The shark and I weren't unhappy to see each other go. Now came the easy part. Kim lowered a directional antenna below the boat.

KIM HOLLAND Okay, if you just wag the nose we should start picking up the signal. Here it is. That's our fish. That's the transmitter. And it's at the surface, because it's a very steady, once per second. If it was deeper, it would be faster.

ALAN ALDA I see.

KIM HOLLAND So, our fish is now dead ahead of us at the surface. Okay, this fish is doing about 100 degree course right now which is going to take us right off the tip of diamond head, which is a very familiar theme for us. Three or four of the previous sharks we tracked have come along exactly this path. Cut off the tip of diamond head and then strike out into blue water between here and the next island of Molokai.

ALAN ALDA (NARRATION) Typically, Kim and his team stay on the track of a shark for as long as the batteries in its transmitter last - about 48 hours. They've tracked about a dozen tiger sharks so far - and every one has wandered far away from where it was caught. This was a big surprise - and bad news for advocates of shark control.

ALAN ALDA What would happen if there was a really bad attack here by a shark and the people went out in boats and killed all the sharks, all the tiger sharks, they could? What effect would that have?

KIM HOLLAND It probably wouldn't have any effect on the number of shark attacks on people. The reason being that we are showing that these fish move much greater distances than we anticipated they would. And that means if you take out some sharks from one beach, they could very easily be infilled by other sharks coming from 30, 40 or 50 miles away. So, at this point it looks as though it would be difficult to have a surgical strike.

ALAN ALDA Okay, okay, look, a lot of people don't care if there are fewer sharks. I mean, I think some of us think of them like rats. If there were a few less rats, it wouldn't hurt. What place in our lives do they hold? Why should I care if the tiger shark disappears or not?

KIM HOLLAND The proliferation of rats is a manmade phenomenon. They live in towns and cities that we've created. Tiger sharks live in an environment which is still essentially unchanged. And as such they are in balance with their environment. And the balance between them and the food that they eat, and the food that their food eats, is still pretty much the way we think it evolved over evolution. And so by perturbing the system by taking out the big sharks, you will actually have an effect all the way down through the food chain.

ALAN ALDA (NARRATION) The tiger shark is just one of 19 shark species that live around Hawaii. All have their mysteries. But none is stranger than this one - the hammerhead shark. A day after wrestling tiger sharks, I joined Kim and his student Chris Lowe in Oahu's peaceful Kane'ohe Bay...fishing for baby hammerheads.

ALAN ALDA Yea, there it is. I see it. It's a little guy.

KIM HOLLAND That's the most common top level predator in the bay. There's thousands of those pups of that size in the bay. So we are going to drop it in the tank now and we can just run a couple of hundred yards back to the lab, and we've got our fish.

ALAN ALDA How big do they get to be?

KIM HOLLAND An adult scalloped hammerhead would be about 14 feet.

ALAN ALDA 14 feet, so these guys are really little, they are young.

KIM HOLLAND These are neonatal pups, they have only been born maybe, the biggest one maybe 3 or 4 or 5 weeks ago, and the smallest ones, maybe a few days ago.

ALAN ALDA This is the most interesting looking fish I have ever seen. Why do they have a head like that? Why is it shaped like that?

KIM HOLLAND Probably for several reasons, one is that they have an eye on each end of the head, so it helps them with binocular vision, they also have a nostril on each side of the head. So that probably helps them to orient to smells in the water, they also have an array of electroreceptors all the way, see those shadows there, those are electroreceptors. They can detect the electrical currents emanating from small prey that they feed on that might be buried just under the sand.

ALAN ALDA (NARRATION) The hammerhead certainly appears to use its head like a metal detector when searching for prey. But Chris Lowe wondered if the head's wing-like shape also gives it a lift - literally - when it comes to swimming.

CHRIS LOWE So we can look at this by placing the shark in my swim tunnel, or my treadmill for fish.

ALAN ALDA (NARRATION) Water flows through the tank from left to right.

CHRIS LOWE So what happens is I can change the velocity of which the water moves through the loop. And once the sharks are conditioned, they will swim in place.

ALAN ALDA This shark always has to keep swimming.

CHRIS LOWE Exactly. I mean, as an obligate swimmer, meaning that from the time it's born to the time it dies, this shark has to swim in order to respire.

ALAN ALDA Day and night?

CHRIS LOWE Day and night. Constantly.

ALAN ALDA Otherwise, what happens?

CHRIS LOWE Otherwise it will suffocate.

ALAN ALDA (NARRATION) If you have to swim to breath, it pays to be as efficient a swimmer as possible. And for the first time, Chris' shark treadmill has allowed him to compare the swimming efficiency of hammerheads to that of sharks with more conventional front ends.

ALAN ALDA Have you been able to show doing this experiment that the head does give the fish an advantage?

CHRIS LOWE These sharks, compared with other species, are very efficient swimmers. And if you look at, for example, the tail, compare the tail of the hammerhead with another species of shark, the tails are fairly similar. So if the tails are similar, how can the hammerhead be more efficient? The only thing I can think of is their wing-shaped head.

ALAN ALDA (NARRATION) A couple of days with Kim Holland and his students was an exhilarating - if scary - reminder of how much there is still to learn about the creatures of the deep - even such celebrities as sharks.

ALAN ALDA You know when we were out on the ocean there, I felt like we were chasing Moby Dick a little bit. I was a little worried first of all that he was going to come and smash our boat apart the way he did in the book. But you're chasing something, like Ahab, what are you chasing?

KIM HOLLAND I'm chasing an understanding of how the parts fit together. Even when it's a big ugly part like a tiger shark, which after a while aren't so ugly. But I have a feeling of real urgency about how fast our marine resources can be frittered away. And I and my students are trying to get the kind of scientific information that will allow us to use the marine resources without squandering them, so that they are going to be there for the next generation.

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HIDDEN DEPTHS

ALAN ALDA (NARRATION) Early morning fog shrouds the harbor of Moss Landing, 75 miles south of San Francisco, as the research vessel Point Lobos heads out to sea. Operated by the Monterey Bay Aquarium Research Institute, its destination is the edge of the last great unexplored region on earth. Just 10 miles out, the ocean floor plunges into a canyon bigger than the Grand Canyon, poising the Point Lobos over water as deep as almost any in the world's oceans. Below the top few hundred feet, these depths were until recently almost entirely unknown, though by volume they make up more than 90% of the earth's living

space. On board the Point Lobos is one of the first regular visitors to these hidden depths, the submarine Ventana.

ALAN ALDA What is all this stuff here?

BRUCE ROBISON Well, we've got a variety of tools that we use at depth. These are samplers that we use to collect the more fragile and delicate animals. Down here is the big eye. Up here along this middle bar are four metal halogen lights. The depths we'll be working at today are very dark. Less than a hundredth of a percent of the sunlight which reaches the surface penetrates as deep as we'll be working today.

ALAN ALDA If we were down there without a light, what would it be like? Would it be like being in a room that just has a tiny crack somewhere under a door?

BRUCE ROBISON Even less than that. About the only thing you can see is that looking up towards the surface is less dark than looking down.

ALAN ALDA (NARRATION) Bruce Robison has been using the Ventana to explore the darkness below for some 7 years now. The submarine has no crew. Bruce and his crew operate it remotely from the surface, where the ocean swell is making life distinctly uncomfortable for me and our camera crew. Unfortunately, going below only makes things worse. The control room is small, dark, hot and constantly pitching. As I munch saltines to settle my stomach, the pilot takes the Ventana on a dive that will penetrate a half-mile into the darkness. The view from Ventana's camera is like something out of Star Wars...

ALAN ALDA So we're just traveling through space here, it looks like we're, oh what went by? Something good went by. What was that?

ALAN ALDA (NARRATION) ...complete with aliens.

BRUCE ROBISON Oh, Peralia. Peralia.

ALAN ALDA What's that?

BRUCE ROBISON These are great big, brown colored medusi.

ALAN ALDA Oh, that's gorgeous.

ALAN ALDA (NARRATION) In a sense, the creatures down here are like aliens...

ALAN ALDA Look at this guy.

ALAN ALDA (NARRATION) ...adapted to an environment quite unlike the one the rest of us who live on earth inhabit. This creature is called a siphonophore.

BRUCE ROBISON This is the propulsive end. There are two swimming bells, one on either side, that allow the animals to pull itself through the water.

ALAN ALDA (NARRATION) In fact, the siphonophore may not be a single animal at all but an assembly of many. Until it was seen here in its habitat, no-one knew much about it.

ALAN ALDA You couldn't have ever brought this up in a net, could you?

BRUCE ROBISON No. We would have had only bits and pieces. We wouldn't have known how many siphonophores were there, whether there was 1 or 100. These animals get to be extraordinarily large. We have measured them up to 120 feet long. That is a very big surprise.

ALAN ALDA (NARRATION) And it makes it one of the longest creatures on earth. Capturing siphonophores and the deep's other gelatinous creatures in one piece is a job for one of Ventana's specialized collection devices.

ALAN ALDA You gonna put him up the vacuum cleaner there?

BRUCE ROBISON That's right. We're gonna draw this siphonophore into the suction sampler. So that we can look at it's stomach contents.

ALAN ALDA You can get a big guy like that into one of your containers?

BRUCE ROBISON Sure.

ALAN ALDA And it wont break?

BRUCE ROBISON It will be, what's the polite term, "wadded up".

ALAN ALDA Ha, Ha. This is why I don't believe in flying saucers coming down and taking samples of humanity. I don't want to be "wadded up" by one of those things.

ALAN ALDA (NARRATION) The siphonophore is gently sucked aboard in one piece - accompanied by some of the dust-like particles that are everywhere down here.

ALAN ALDA What's all this snow-like stuff we are seeing around the animals?

BRUCE ROBISON You called it by the right name. We refer to it as marine snow. It's sort of all of the junk and detritus and dust of the upper layer of the ocean.

ALAN ALDA So, that's stuff falling off of animals up above. And it passes through this region and continues on it's way all the way down to the bottom?

BRUCE ROBISON That's right.

ALAN ALDA And animals are feeding on it all the time?

BRUCE ROBISON Yes, certainly bacteria feed on it while it descends. But there are other animals, filter feeders, that occur in mid-water, and they process these particles. But eventually, they all reach the sea floor.

ALAN ALDA (NARRATION) Since Bruce Robison and his colleagues began their deep water explorations, they've identified dozens of new species. Creatures down here range from the gruesome fangtooth... to the angelic-looking ribbonfish. Some 2100 feet down, the Ventana passes through a layer where oxygen levels are very low. Among the creatures adapted to hanging out here is the splendidly named *Vampyroteuthis infernalis*, a distant cousin to octopus and squid. It glares at us balefully through a huge blue eye.

BRUCE ROBISON Oh boy, time out. This is a paralepidid. A very, very beautiful little fish that we don't see all that often. It's nose is up, it's keeping itself almost vertically in the water column. It's looking up trying to see it's prey silhouetted against the surface. Very soon, it's going to take off and it will be gone just like it vaporized. There he goes. He's history.

ALAN ALDA (NARRATION) To evade shadow stalkers like the Paralepidid, potential prey are often transparent... Or, like this little fish, they generate their own internal light. When viewed from below, this makes them less visible against the lighter surface. Bioluminescence is used a lot down here. The otherwise-black angler fish has a luminous beard to attract prey. But why so many animals glow in the dark is still a mystery.

BRUCE ROBISON This is a red-bellied tomachtarid. It's a type of polechite worm that lives down here. This animal has bioluminescent organs at the ends of all it's legs.

ALAN ALDA What a great shot that is.

BRUCE ROBISON It's like having glowing toes.

ALAN ALDA (NARRATION) There are so many questions down here. This catcher's mitt shaped creature seems to propel itself along with shimmering hairs along its edge, but otherwise is utterly mysterious.

ALAN ALDA How does this animal reproduce?

BRUCE ROBISON Good question, I don't know.

ALAN ALDA Ha, Ha. Well, you know what's wonderful is how much there is to learn down here.

BRUCE ROBISON Oh sure.

ALAN ALDA It's a whole other universe.

BRUCE ROBISON That's part of what makes it so exciting. Each dive can, and often does, bring us something new, something unexpected.

ALAN ALDA (NARRATION) Unfortunately, my own curiosity had begun to lose its battle for attention with my stomach.

ALAN ALDA I think I have to go up and get some air.

BRUCE ROBISON Okay.

ALAN ALDA It's not that this isn't fascinating. But I think staying in one piece will be more fascinating.

BRUCE ROBISON Certainly more enjoyable.

ALAN ALDA (NARRATION) Up in the light and air, it's hard to believe that just beneath us lies the earth's strange final frontier. Pioneers like Bruce Robison will be exploring its mysteries for many years to come.

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SHELL GAME

ALAN ALDA (NARRATION) Low tide at Pillar Point, a scenic spot on California's coastal highway. It's a favorite spot, too, for biologist Gary Vermeij, when he's out searching for insights into one of nature's longest running arms races. Gary searches - or as he puts it, sees - with his hands and fingers. Blind since the age of 3, it's through touch that he sees things most of us with sight would miss.

GARY VERMEIJ Lets see what he's up to. What are you doing? Ah ha! What have you got there. Looks like a tegula. Yes indeed, absolutely, he had a tegula, a tegula funebris - a snail. He had this snail sitting right like this, and his mouth was over the opening of the snail, and he was clearly digesting it. What they do is, they have this stomach that they can extrude through the opening of the shell into the snail and digest it externally. It's kind of a slow, miserable way to go, but it's what they do. You just do your thing here, find another tegula.

ALAN ALDA (NARRATION) It was no contest between the starfish and the snail. But Gary is fascinated by how mollusks like the snail have evolved defenses against their predator's weapons - leading him occasionally to confront those weapons himself.

GARY VERMEIJ Yes, I'm afraid of getting bitten or something, but it doesn't happen very often. In any case I think it's worth the effort because you always find something interesting.

ALAN ALDA (NARRATION) To Gary, no shell is without interest - even one that's been almost entirely demolished.

GARY VERMEIJ This is a lethally broken tegula funebris. I don't know who killed it, or what killed it - it could have been a crab. It's been pretty badly mashed. That was definitely a fatal wound.

ALAN ALDA (NARRATION) But it is shells that have survived the attacks of their predators that Gary finds most intriguing. Because in their scars he sees their life stories

GARY VERMEIJ I imagine a crab or something got at this shell, broke the lip back about 90 degrees. The animal survived and repaired the damage and is now back to normal. This animal had a rather eventful life.

ALAN ALDA (NARRATION) The daily skirmishes along the seashore that Gary reads in the shells he finds are the latest in a confrontation that's lasted hundreds of millions of years. Back in his office at the University of California in Davis, Gary uses his Braille typewriter to catalogue the thousands of shells he's collected in field trips around the world. He keeps abreast of what's happening in evolutionary biology with Braille transcriptions of the journals - including the leading journal in the field, of which he is the editor. Gary Vermeij has never let his blindness stand in his way.

ALAN ALDA You must have had a very, very strong upbringing.

GARY VERMEIJ I had an exceedingly strong upbringing. My parents were, what I consider to be quintessentially level-headed Dutchmen. They never heard of failure, they never heard of giving up.

ALAN ALDA (NARRATION) On our way to his office, we stopped at a sculpture garden.

ALAN ALDA Actually, this one looks a little like a crab claw.

GARY VERMEIJ Ha Ha.

ALAN ALDA But the claws are up high here.

GARY VERMEIJ Yea, now that part is nice and smooth. Would you feel this, this is ugly, it's rough.

ALAN ALDA I don't focus on this cause I'm looking at the whole shape.

GARY VERMEIJ People look at this, so they don't have to feel it. If they had to feel it, they'd say "ugh, it's just a rock". And of course now it's nice and warm because it's in the hot sun.

ALAN ALDA Yea. That's right. That's something that you get that you don't get if you're just looking at it.

GARY VERMEIJ That's right. You can't feel the cold stone.

ALAN ALDA You're getting the changes in temperature on various sides of this. The idea that you may see things that we don't - like this texture and temperature - things that I would never have thought of as part of the enjoyment of the sculpture. It's very interesting because do you suppose you see things therefore in shells that other people don't see?

GARY VERMEIJ I'm not sure I see things that others don't see. I may emphasize some things more than other people would. But I think I essentially see the same thing.

ALAN ALDA (NARRATION) We began our tour of Gary's lab with a demonstration of what shells are up against.

ALAN ALDA How strong are those claws?

ED LEWIS Oh, I'll show you.

ALAN ALDA (NARRATION) This is Ed Pearson, one of Gary's graduate students.

ED LEWIS Grab on to my pencil here, and give it a little shake.

ALAN ALDA She's really clamping down now. I can really see how she could break a shell with that strength.

ED LEWIS Oh yea, I've broken a few pencils this way too.

ALAN ALDA (NARRATION) The crab's claws made short work of the snail Ed gave it. But then I got to serve up a different tid-bit...

ALAN ALDA Yoo hoo, lunch.

ALAN ALDA (NARRATION) It was potentially as tasty but in a trickier package. And this time, despite several minutes of probing for a weak spot, the crab gave up and the shell survived unscathed.

ALAN ALDA That is a teradactyl.

GARY VERMEIJ Yes it is, a teradactyl.

ALAN ALDA (NARRATION) Gary's passion is to learn how these survivors evolved.

ALAN ALDA Do any of your shells go back that far, or further?

GARY VERMEIJ A couple of them. Most of the ones I work on are since the age of dinosaurs. Let me show you a volema, that has a truly horrid scar on it.

ALAN ALDA (NARRATION) His favorite fossils are survivors who lived to repair their battle wounds.

GARY VERMEIJ This a really dreadful, it has sustained this attack right here which isn't so bad, and back here when it was much younger, look at this, this is terrible...

ALAN ALDA Oh, big crack like. Now, this is all scarred, it's not a pretty shell, and yet this is valuable to you and your work, right? More than a pretty shell.

GARY VERMEIJ You bet. Yes, well it tells you a lot. This is an animal that records, it chronicles it's own history very nicely.

ALAN ALDA (NARRATION) The history Gary sees chronicled in his fossil shells is of repaired damage becoming more frequent over evolutionary time, suggesting more shells are surviving the attacks of their predators as their armor becomes more sophisticated. Meanwhile, of course, their predators were evolving ever more fearsome shell-crushing weapons of their own.

GARY VERMEIJ This happens to be a box full of one set of stomach contents of a fish.

ALAN ALDA Now, how did this get broken? Did a fish chew on it first?

GARY VERMEIJ Yes, the fish has a jaw. This is it. Of course these are upper and lower, and they crush.

ALAN ALDA So, they crush it between those rough plates.

GARY VERMEIJ Yeah, like a vice.

ALAN ALDA (NARRATION) But some shells came up with an ingenious solution.

GARY VERMEIJ If it has long spines, it makes the shell larger. For example, this is a truly unusual example.

ALAN ALDA That's pretty spiny.

GARY VERMEIJ Yea, it's pretty spiny. Well, these spines actually make the shell, in a way, bigger than it really is. So, it's harder to put into the jaws.

ALAN ALDA Oh, I see. It's not that, I thought the spine would act like kind of a spear or pike or something.

GARY VERMEIJ No, it simply makes it bigger

ALAN ALDA It doesn't have to grow so big, it just puts out little spikes

GARY VERMEIJ That's right.

ALAN ALDA (NARRATION) Spines aren't the only defense mollusks have evolved. Others grew longer, giving the soft animal inside room for retreat. Some shells evolved buttressing to strengthen the vulnerable opening...while others close tightly...or - like this cowrie - have a small opening and a slippery surface. All these adaptations are in response to predators that have also been evolving.

GARY VERMEIJ So, for animals with skeletons like mollusks, the world has changed a lot. You have to meet higher standards that one might have had to meet hundreds of millions of years ago. You're not necessarily better off today. But it's kind of like human beings. We have to put up with heavier weaponry, with guns, whereas, you know, in the 1200's, or whatever, we only had to put up with arrows.

ALAN ALDA These caught my eye. These are incredibly beautiful.

GARY VERMEIJ Oh yes, wonderful fossil.

ALAN ALDA This incredible beauty was developed through an arms race apparently, through conflict.

GARY VERMEIJ For every organism that lives, an awful lot have died and an awful lot have suffered.

ALAN ALDA Yea. You know I think about this so called balance of nature in a different way now that you say that because I guess nature looks like it's in balance and everything seems comfortable unless you happen to be one of the things getting pushed off the scale to bring it into balance.

GARY VERMEIJ That's right. We have to always remember that the world we are looking at for the most part is a world of survivors and a world of the successful.

ALAN ALDA And from that kind of surviving of conflict, you get these beautiful shells.

GARY VERMEIJ Yes.

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SPINELESS BUT SMART

ALAN ALDA (NARRATION) One of my most memorable encounters with a creature of the deep came last year, at a fish market on the Bay of Naples in Italy. I was there with biologist Graziano Fiorito - who wasn't shopping for dinner but for subjects to take part in an extraordinary experiment.

ALAN ALDA What about these guys?

GRAZIANO FIORITO These are good enough.

ALAN ALDA (NARRATION) This is the animal Fiorito works with -- the octopus, one of the least-loved creatures of the sea. At first it's hard to figure out just how the octopus is put together.

ALAN ALDA Where are his eyes?

GRAZIANO FIORITO The head is this. This is eyes.

ALAN ALDA And what's this? It looks like a big nose.

GRAZIANO FIORITO This is the abdomen of the animal.

ALAN ALDA Oh, the abdomen. It's not his nose. And where's his mouth?

GRAZIANO FIORITO The mouth is underneath.

ALAN ALDA In the middle of his hands.

GRAZIANO FIORITO Yes, here, you see it.

ALAN ALDA (NARRATION) Graziano Fiorito takes his subjects back to the zoological station in Naples, Europe's oldest marine biology laboratory. As an invertebrate, the octopus may be spineless but it is a skilled hunter. Lurking behind a rock, this one is stalking a hermit crab. Octopuses live alone, so it's thought that their hunting skills are partly pre-programmed in their genes and partly self-taught from experience. The idea that a creature as lowly as an octopus might also learn as we do, by watching others, would be heresy to most scientists. But that's just what Fiorito believes he's seen. Here's the challenge he sets for the octopuses he buys from the market - a glass jar containing a crab, and sealed tightly with a plug. Some octopuses, perhaps because they've opened a lot of shells for their dinner, open the jar on their first try. Others, like this one, can be given the jar time and time again without getting inside. I joined Fiorito for the key experiment. The octopus on the right is the one that can open the jar. The one on the left can't.

ALAN ALDA You already gave him a jar and he couldn't do it?

GRAZIANO FIORITO No. Half the population of animals that come from the sea are able to do it and the other half they are unable to do it. So it depends let's say from the individual's experience. There are some octopus that are more skilled than other ones.

ALAN ALDA (NARRATION) The unskilled animal will be given a chance to watch how it's done.

ALAN ALDA So now the octopus over here in this tank is going to watch this one open the jar.

GRAZIANO FIORITO That's right.

ALAN ALDA (NARRATION) Even knowing how to do it didn't help me.

ALAN ALDA I need suction cups on my fingers here. I can't do it.

ALAN ALDA Does he see it yet do you think?

GRAZIANO FIORITO Yes.

ALAN ALDA (NARRATION) The skilled octopus sees the crab immediately and moves in. The unskilled octopus seems to be watching intently, as the skilled one explores the jar.

GRAZIANO FIORITO It's crawling now on the jar and it recognizes the plug. Now its behavior is changed - now it's carrying it right back home to be more safe from the other animal.

ALAN ALDA He doesn't want the other animal to interfere?

GRAZIANO FIORITO That's right.

ALAN ALDA (NARRATION) The performer pulls the plug and the crab is his. Meanwhile, the observer octopus is scrambling for the best view.

ALAN ALDA Do you think that this animal from observing that this time may know how to do it?

GRAZIANO FIORITO We can try.

ALAN ALDA Great, can we see?

ALAN ALDA (NARRATION) Now remember, this animal has never before been able to open the jar. What's new is that he's observed the solution.

ALAN ALDA Oh here he goes, here he goes. Look, look, look, look. Oh wow, look at him. Just went right at it.

ALAN ALDA Look, he got in, he got it open. And he was never able to do that before?

GRAZIANO FIORITO No.

ALAN ALDA This is unbelievable.

ALAN ALDA (NARRATION) What Graziano Fiorito has shown for the first time is that an invertebrate can learn by observing. Social learning like this is a domain of intellect usually reserved for mammals like us. But as I learned in the fish market, you have to you know how to handle an octopus if you want it to show you its secrets.

ALAN ALDA Why do you need to be relaxed with an octopus?

GRAZIANO FIORITO If you would like to study behavior of animals the animal must be sure that you would never kill him. There is such a kind of, let's say, good relationship between you and the animal, a good feeling.

ALAN ALDA You have to have a sure touch, huh? Well I don't have it. I think these animals can sense it.

GRAZIANO FIORITO Yes, they are sensitive.

ALAN ALDA What's the best way to pick them up?

GRAZIANO FIORITO Here ...

ALAN ALDA Oh, ho. Ohhh. How do you get used to this? You like that?

GRAZIANO FIORITO Yeah.

ALAN ALDA It's a little like a hand full of worms.

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WHALE WARNING

ALAN ALDA (NARRATION) The mournful cry of a humpback whale. Racing to saving its life is a team of biologists from Memorial University of Newfoundland, led by Jon Lien. The whale is trapped in a fishing net. Unless it can be freed, it will probably die. This scene was filmed in 1992, at a time when it was tragically common in the fishing grounds of Newfoundland's Grand Banks. The work was difficult and dangerous. Jon Lien had to repeatedly plunge himself into water just a few degrees above freezing as he tried to free the 30-ton whale. He's been involved in some 500 such whale rescues. This time the struggle has already

lasted almost 3 hours. Partially free, the whale is now dangerously mobile. Then with one final cut - freedom. The whale had been entangled in a cod net. And it was as important to save the net as it was to save the whale.

JON LIEN Our fishermen do not earn a lot of money, they have a big investment, they have a very short season, and it's a real tough job. So, when a whale comes and hits their nets right in the middle of fishing season, they might lose enough time that they could lose their whole years voyage. So, it's a serious problem for the fishermen.

ALAN ALDA (NARRATION) But the Newfoundland fishermen were facing an even more serious problem - the near total collapse of a fishery that had sustained this region for centuries. When John Cabot discovered Newfoundland 500 years ago, he reported cod so plentiful he didn't need a net to catch them. As recently as the 1950's, Cabot's claim was believable. But in the decades that followed, local fishermen using traditional dories and much larger foreign fishing vessels - had so overfished the Grand Banks that cod nets were coming up emptier and emptier. Just after FRONTIERS filmed here in 1992, the Canadian government closed down the Grand Banks to all commercial fishing. The decision was a reprieve for the humpback whales. But its intent was to allow cod stocks to replenish, so that one day fishing can resume. By the time it does, researchers hope to fully understand why whales apparently don't detect cod nets until it's too late, but rarely get entangled in the finer nets used to catch smaller fish like capelin. That's why Sean Todd of Memorial University is setting out to compare cod nets and capelin nets. But not to find out if they look different to whales. Sean wants to learn if they sound different.

SEAN TODD What we're doing is we're basically just comparing cod traps, capelin traps, and any other gear we can find in the water and see what kind of sound they make. And hopefully, by looking at the kind of sounds they make, we can get an idea of how probable it is that a whale will hit the trap.

ALAN ALDA (NARRATION) Using an underwater microphone, Sean has recorded the sound of dozens of different nets. The sound is made by the water rushing through the net's mesh.

SEAN TODD What I'm hearing right now is basically acoustic nonsense. It's just nothing but, what we call, white noise. It's kind of like a noise. You can't make any sense out of it because our ears really aren't sensitive enough to hear what's going on. But, we do have machines back in the laboratory that can work out exactly what this sound is saying.

ALAN ALDA (NARRATION) When the sound is analyzed, capelin nets - with their fine mesh - are far noisier than the wider-mesh cod nets, which under water are

almost silent. This discovery led the Newfoundland researchers to a simple idea: make cod nets noisier by fitting them with alarms.

JON LIEN If we pull up along side here we can give you some alarms and have a chat.

ALAN ALDA (NARRATION) In the last year of cod fishing here, Jon Lien paid a visit to fisherman Ken King. King was trying out an experimental alarm - which was still having problems.

JON LIEN When you haul, do you lift up your alarms and listen to them?

KEN KING The boys lifted them up Thursday past.

JON LIEN And you can hear them ticking?

KEN KING Everyone was ticking except the one on the inside end of the leader, it was a real low tick.

JON LIEN I don't know, we're having some problems with them in the cold water. We bought cheap batteries this time, trying to save a bit of money.

ALAN ALDA (NARRATION) Jon Lien's experimental alarms didn't save this humpback whale - one of the last to die entangled in a cod net before the fishing moratorium took hold. But its death may help make the alarms more effective once commercial fishing resumes. Because buried deep within the whale is the key to the alarms' effectiveness - if only they can get to it. For the whale alarm to work, the animal must be able to hear it. And very little is known about what whales hear for one very good reason. Its ears are buried under layers of blubber. It's not an operation for the faint-hearted, when every cut releases the gases of decomposition.

JON LIEN Oh gees, watch out, I'm going in. Oh, God! I filled my boots.

ALAN ALDA (NARRATION) But for Jon, it's all worth it.

JON LIEN Well I think for a scientist, it's just amazing how this huge animal works. We only understand it very poorly. And it's a rare privilege to be able to get inside of it like this. Even though its kind of gross. To begin to see how the parts fit together. How they might make the animal work. So, it is a little smelly, and it's a little bloody, and you get wet, but it is absolutely fascinating.

ALAN ALDA (NARRATION) After hours of work, Jon finally finds what he is looking for - the humpback's ear. To find out if it can hear his alarms, we went to the Massachusetts Eye and Ear Institute - and the lab of Darleen Ketten.

DARLEEN KETTEN This is what I call an ear. Look at that. What a beauty. A whole ear, it's gigantic. All right, so what we've got is the middle ear portion, the bone that makes the middle ear, the eardrum coming out, it's called a glove finger for obvious reasons, and then this is the section that's of the most interest to me, the inner ear part, which sits down on here. And then there is a flange, which is currently broken off, but which attaches to that and connects the whole ear to the skull.

ALAN ALDA (NARRATION) Occupying the spot more usually taken by the head of a human patient, the ear is CAT-scanned and the scans are assembled by computer into a 3-D image.

DARLEEN KETTEN Yes. There it is. Here is that inner ear spiral, just sitting right in there as it ought to be with 2 1/2 turns to it.

ALAN ALDA (NARRATION) It's this spiral that holds the key to exactly what the whale can hear. Because within it - as this computer graphic shows - there's a flat membrane that vibrates in response to sound.

DARLEEN KETTEN You can think of it as a whole series of guitar strings of different stiffness and different mass, all strung together each one of these bits as it gets narrower, it gets thicker or stiffer. So, that's the most taut string. And at this end it's where it's very thin and floppy is the least taut string, and that's where the lowest frequency parts are.

ALAN ALDA (NARRATION) To determine the range of frequencies the membrane detects, the spiral is sliced into ultra-thin wafers that can be viewed under a microscope. The alarm Jon Lien is testing to warn humpback whales away from cod nets rings at a frequency of 4 kilohertz. From her measurements of the membrane - and a mathematical model she's devised - Darleen Ketten can confirm that this is an ideal frequency for alerting marine mammals to danger.

DARLEEN KETTEN What I've done is to plug it into the model and out of that we get a range that goes, in this case for the humpback, from about 20 hertz up to about 30,000 hertz or 30 kilohertz. It's actually pretty close to what a human hears. So, an alarm, for instance, that's around 4 kilohertz to 5 kilohertz is good for the humpback. It's pretty much smack dab in the middle of what it can hear as a total range. It's good for something like a sperm whale, and it's even good for a harbor seal or a sea lion, say, or even a human.

ALAN ALDA (NARRATION) The clinking of the alarm fisherman Ken King was testing before fishing stopped seemed to be successful in warning off whales without frightening away the cod.

KEN KING Last year when I had a cod trap here in the same area, it was tore up every day, never missed a day, had a tear up, holes in the leader, holes in the trap, and then I contacted Jon. I got 7 of these alarms, I put 4 on the box, and 3 on the leader. And the sound that they made, I thought they would frighten the fish, but the best catch I ever had for the season, for one day at 22,000 the day after we put these things on. I knew it didn't frighten the fish, and for the 6 or 7 days after that we had them on, the fish got a little less because it was gettin toward the end of the season. But, no more whales, thank God.

ALAN ALDA (NARRATION) One day, cod nets will again hang in the waters of the Grand Banks. When they do, the clinks of Jon Lien's alarms could be a life-saving accompaniment to the songs of the whales.

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