Brains On (APM) | Brains On! How do animals breathe underwater? (Encore)
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MOLLY BLOOM: Hi there, *BrainsOn!* listeners. Molly here. Before we start today, this is something that a lot of you have been asking for, and we're really excited that it's here.

[MUSIC PLAYING]

We now have *Brains On!* t-shirts for sale. You can go to brainson.org/shop to see them. There's a couple that we're particularly excited about. We wanted a way to show how smart and curious our listeners are, and so there's one shirt that says, "Ask me about Europa" with an awesome design and then Brains On! on the back. That's a nod to our episode about life on other planets, because you guys are experts on that now.

And then there's another that says, "Ask me about sauropods," because who doesn't want to share their dinosaur knowledge with the people they meet? So you can head to brainson.org/shop to check out those awesome t-shirts. All right. Now onto the show.

SPEAKER 1: You're listening to *Brains On!* where we're serious about being curious.

SPEAKER 2: *Brains On!* is supported in part by a grant from the National Science Foundation.

MOLLY BLOOM: Deep breath in.

[INHALES]

Deep breath out.

[EXHALES]

SIERRA: Deep breath in.

[INHALES]

Deep breath out.

[EXHALES]

MOLLY BLOOM: Our lungs are great at getting the oxygen we need from the air. But if they needed to do that in the water?

SIERRA: Not so much.

MOLLY BLOOM: There are plenty of creatures that can, however, breathe underwater.

SIERRA: How do they do it?

MOLLY BLOOM: We'll find out right. Now keep listening and breathing.

You're listening to *Brains On!* from American Public Media. I'm Molly Bloom. And here with me today is 10-year-old Sierra Haro from Los Angeles. Welcome, Sierra.

SIERRA: Thank you, Molly.

MOLLY BLOOM: It was Sierra's interest in the ocean and marine life that inspired this episode. So, Sierra, how did you first get interested in the ocean?

SIERRA: Well, last summer, I went to SeaWorld, and I saw all these sea creatures. And I was very worried about the environment that they lived in and their habitat.

MOLLY BLOOM: And do you ever go to the beach and observe the sea life around there?

SIERRA: Yeah, I've been to Redondo Beach with my mom and my sister. And we see kelp washing up at the shore. We see little seashells on the sand. We see different marine kind of life. Sometimes we see seals coming up on the shore.

MOLLY BLOOM: There are so many cool things about oceans and the life down there that we could do many, many episodes on that alone. Today, we're focusing on just one of the fascinating things about the creatures living in the ocean.

SIERRA: Their ability to breathe underwater.

MOLLY BLOOM: There are all sorts of sea creatures that use gills to breathe.

SIERRA: You can think of gills as kind of like our lungs. We use our lungs to breathe in oxygen.

MOLLY BLOOM: Yup. And gills are the organs many animals use to absorb life-sustaining oxygen from water. Gill-breathers include mollusks.

SIERRA: Clams and oysters.

MOLLY BLOOM: Arthropods.

SIERRA: Like lobsters and crabs.

MOLLY BLOOM: Echinoderms.

SIERRA: Like starfish and sea urchins.

MOLLY BLOOM: Cephalopods.

SIERRA: Like cuttlefish and octopuses.

MOLLY BLOOM: And of course, fish.

SIERRA: They all have gills. But how does gills work?

MOLLY BLOOM: To find out, I talked to Nick Phelps from the University of Minnesota.

NICK PHELPS: I'm the fish guy.

MOLLY BLOOM: He researches fish in the College of Veterinary Medicine. And he knows all the ins and outs of gills.

NICK PHELPS: Gills are incredibly important, and they're an amazing organ.

MOLLY BLOOM: Oxygen gas is dissolved in oceans, lakes, and rivers. In order for these animals to absorb that oxygen, they need to move the water over their gills. In the case of fish, they do this by sucking water in through their mouth.

SIERRA: Gills look like they're covered in tiny feathers. And those feathers are what's absorbing the oxygen.

NICK PHELPS: We have what are called epithelial cells. They're basically like skin cells, and they're one layer thick on each one of these little feather-like filaments. Water on the outside of that has the oxygen. And the oxygen on the other side, in the blood, is much lower. So through diffusion, so something going from a high concentration to low concentration, that oxygen gets diffused into the bloodstream.

Air that we're breathing has more oxygen than the water does. There is oxygen, obviously, in the water. So the fish have adapted to be much more efficient at taking that out. They can take out much more percentagewise than we can take out through our lungs. So it's a pretty cool way that they've evolved to live in that environment.

So there's tons of these little filaments. And it comes down to surface area. The more surface area that these filaments have, the more oxygen that they can take out. There's more surface area in the gills, probably, than the entire body of the fish. So there's a lot in there.

MOLLY BLOOM: If a fish gets sick, veterinarians can treat the fish by putting medicine in the water or in the fish's food, or by giving it a shot.

SIERRA: But sometimes, that's not enough and the fish will need treatment outside of the water.

MOLLY BLOOM: And since they can't breathe air, their gills need to stay wet.

NICK PHELPS: We can put fish under anesthesia, basically put them to sleep for a surgery, for example. And when you're doing that, you put basically a hose in their mouth, and so water is continually pumped over their gills. So then, instead of the fish doing that themselves, opening and closing their mouth and bringing that water in, we do that mechanically.

SIERRA: Kind of like the oxygen masks that humans use, but in this case, the oxygen is in the water.

MOLLY BLOOM: Gills work the same basic way for all the different creatures that have them.

SIERRA: Water moves over the gills.

MOLLY BLOOM: And the oxygen gas that's in the water gets absorbed through diffusion.

SIERRA: To get an idea of how gills work in other creatures, we're going to tune in to a very special sporting event.

[SPORTS TUNE]

BROCK: You're listening to a live broadcast from the 68th Annual Sea Games. I'm Brock Lobster.

SALVATORE: I'm Salvatore Salmon.

CECE: And I'm Cece Kukes. If you're just tuning in, earlier today, Vinny Viperfish in a stunning upset. He lit up the course and took home the gold in the bioluminescence event.

VINNY: I just want to thank my mom for telling me to never give up on my dreams, and my coach. Genus Chauliodus! Woo! Yeah!

SALVATORE: That kid has a bright future ahead of him. That's for sure.

BROCK: We're going to turn now to the event that everyone has been waiting for.

CECE: [GASPS] Is it time?

BROCK: Yes, indeed, Cece. The--

SALVATORE: Underwater freestyle breathing finals.

BROCK: That was my line, Sal.

SALVATORE: Oh, sorry, Brock. I just get so excited.

CECE: OK, guys. Let's focus here. We have three creatures anxiously waiting to see who will float away with the Golden Trident. Representing fish, we have Anne Chovy.

ANNE: Bring it on. I am so ready for this.

CECE: And representing the cephalopods, we have Arturo Octopus.

ARTURO: Thank you. Thank you. You're, you're very kind. Thank you.

CECE: And the one who has already become a star in everybody's mind. Bringing it home for the echinodersm, Stella Starfish.

STELLA: I made it. I can't believe I'm here.

BROCK: First to take the floor will be Anne Chovy. Here she goes.

CECE: Sal, you represented fish in the 50th annual games.

SALVATORE: Hmm-mm.

CECE: What do you make of her technique?

SALVATORE: Well, she's off to a swimming start. And nearly flawless.

CECE: Ooh, nice maneuver.

SALVATORE: Yes. Cece, you see how she draws the water in through her mouth and it flows over the gills. Fantastic!

CECE: Oh, you can't argue with that.

BROCK: The judges are sure to give her high marks for technique. But what about style?

SALVATORE: Oh, she's swimming in so many small circles. That takes real stamina. It's hard not to get dizzy.

BROCK: But a bold enough choice for the finals? Hmm. We'll see.

[SPLASHES]

CECE: Whoa! Did you see that? She stopped right there just above the coral.

BROCK: What a routine! Such gills!

SALVATORE: Let's see what the judges think. 7.5. Yikes! Well, the Golden Trident may have just floated out of reach.

BROCK: Well, I see Stella Starfish getting ready to start.

SALVATORE: The thing I love about starfish is the--

CECE: I believe they prefer to be called sea stars.

SALVATORE: Really? Well, OK. My bad.

CECE: Hush. She's starting.

BROCK: Are you sure? It looks like she's just sitting there.

SALVATORE: Well, she is moving just incredibly slowly. Her sheer determination is incredible.

BROCK: Anne Chovy was somewhat limited in that she had only two gills.

SALVATORE: Right. You see the fuzzy fur-like patches on Stella's back?

BROCK: Oh, yeah.

SALVATORE: Those patches are made up of tiny papulae. They're shaped like tiny fingers and allow the starfish to--

CECE: Ehem. See stars.

SALVATORE: Sea stars to absorb oxygen from the water.

CECE: Well, the routine seems to have ended. Though, I'm not really sure.

BROCK: Yes. Yes. Her trainer is coming out to move her out of the arena. The judges are readying the score. 8.3 for Stella.

SALVATORE: What? For that?

BROCK: Sal, do you know what my crusty old dad once told me when I was first starting to watch the games?

SALVATORE: What's that, Brock?

BROCK: Judges going to do what judges going to do.

CECE: Brock, that doesn't even make sense.

BROCK: I'm not about to question it at this stage of my life. All I know is that it got me through some deep water.

CECE: Uh, OK. Well, Arturo Octopus stands between Stella and the gold. Here, Artie comes now. He looks pumped up, doesn't he, Brock?

BROCK: Oh, yeah. Looks like-- is he? Yes, he is. He's lifting weights with all eight arms at once. That's impressive.

SALVATORE: Oh, come on.

CECE: OK, the weights are down. And wow! He's already started.

BROCK: The athleticism! The grace! He's astounding!

CECE: His ability to both swim and crawl is providing some real drama.

SALVATORE: OK. I'll admit it. He is crazy good. But it's hard not to be with a sack-like body that Arturo has.

CECE: All octopuses have that. It's called a mantle.

SALVATORE: Oh, right. The mantle is open on the inside.

BROCK: Artie sucks the water into his mantle where it can move past the gills. When the gills have absorbed the oxygen, the water is expelled through the funnel.

CECE: If the water goes through the funnel forcefully enough, it will propel him forward. That's how octopuses swim. Like now! What a move!

BROCK: And Arturo has a lot of heart.

SALVATORE: You can say that again.

CECE: And again. Arturo actually has three hearts.

BROCK: Each of his two gills get its own heart. Those pump blood through the gills. Then there's another heart to pump blood through his other organs.

CECE: There's the dramatic finish Arturo is known for.

[APPLAUSE AND CHEERS]

Arturo octopus, clearly a fan favorite here at the games. Let's see if the judges agree.

BROCK: 9.8! Wow!

CECE: Arturo octopus takes home the Golden Trident at this year's sea games. Oh, here he comes! Artie, how does it feel?

ARTURO: Whether your blood is blue or red, whether you have a spine or not, whether you have scales, skin, or shell, we're all in this together. We all need oxygen to live. Viva, oxygen! Viva, Sea Games 2015! Viva, Gold Trident, baby!

BROCK: Inspiring words from a champion. Arturo Octopus.

CECE: We're signing off for tonight. But we'll be back tomorrow with the highly anticipated sting and release. Will the jellyfish win a third consecutive gold? Tune in tomorrow to see the exciting competition. I'm Cece Kukes.

SALVATORE: I'm Salvatore Salmon.

BROCK: And I am Brock Lobster, signing off.

MOLLY BLOOM: With the spirit of competition in the air, I have a challenge for you. It's time for the mystery sound.

SPEAKER 3: Mystery sound.

MOLLY BLOOM: Here it is.

[RUNNING WATER]

Do you have any guesses?

SIERRA: Um, maybe water or waves?

MOLLY BLOOM: Yes, there's definitely water involved. And there was another little sound going on there. Do you think-- what do you think is going on in the water?

SIERRA: Um, maybe some movement?

MOLLY BLOOM: Hm-mm. There is movement. We're going to let you absorb that one a little while longer before the big reveal. So think about what possible movement could be in that water.

SIERRA: OK.

MOLLY BLOOM: Now, you may have noticed some sea creatures missing from that competition. Mammals that live in the ocean.

SIERRA: Like whales, dolphins, and sea otters.

MOLLY BLOOM: They have lungs like us and breathe air when they come to the surface.

SIERRA: They can, however, hold their breath much, much longer than we can.

MOLLY BLOOM: Do you know how long a Cuvier's beaked whale can hold its breath underwater?

SIERRA: An hour, maybe?

MOLLY BLOOM: Yeah, it's longer than that actually. They can hold their breath for over two hours. How long can you hold your breath for?

SIERRA: Probably like 30 seconds at the most.

MOLLY BLOOM: Yeah, you're better than me. I think I could probably do mine for like 15 seconds. That's very impressive. And then there's jellyfish. Jellyfish get their oxygen from the water, but not through gills, which they don't have.

REBECCA: My name is Rebecca Helm, and I'm a grad student at Brown University where I study jellyfish. Jellyfish breathe by passing water over their bodies. Water moves over the body of a jellyfish, and oxygen passes from the water directly into the cells of the jellyfish's body.

And part of why they can do this, whereas something like a fish can't really do it and need specialized breathing structures, is because jellyfish are only made up of two cell layers, believe it or not. So most of the jellyfish is actually extra non-living stuff. So it's actually a type of jelly called mesoglia. And there aren't very many cells in it.

And so all the cells are located in a really, really thin layer just right on the outside of the jellyfish and then in another really, really, really thin layer that lines the stomach. And because they only have two cell layers, they don't really need to take in a lot of oxygen, bind it to special molecules, transport it all around the body because those two cell layers are being exposed to water all the time.

MOLLY BLOOM: And if you want to hear more about jellyfish, we have a whole episode all about these amazing creatures. Check it out.

I want to let you know about a cool giveaway we have going on. It's for a book that we featured on the show called, *Does It Fart?* And I know from reading all of your emails and letters that this is a question that a lot of you have. So this book sets out to answer that question for animals all over the world.

Authors Dani Rabaiotti and Nick Caruso were featured on our Animal Fart episode while they were researching this book. And now we have 10 copies to give away. Head over to brainson.org/giveaway for a chance to win. And you can always send questions, mystery sounds, and high fives to hello@brainson.org. That's what Eden and Tabitha did when they sent us this question.

EDEN: Why do we earwax?

TABITHA: And how do we get earwax?

MOLLY BLOOM: We'll have an answer to that question during our Moment of Um, as well as the most recent list to be added to the brain's honor roll. This is how we thank all of you who keep us going by sharing your ideas with us. Listen for all of that at the end of the show.

You're listening to *Brains On!* from American Public Media. I'm Molly Bloom.

SIERRA: And I'm Sierra Haro.

MOLLY BLOOM: So now we know how animals can get oxygen out of water. But how does oxygen get into the water in the first place?

SIERRA: Any kind of surface disturbance--

MOLLY BLOOM: --like a waterfall--

SIERRA: --allows oxygen gas to dissolve in the water.

MOLLY BLOOM: And that oxygen gets spread throughout the body of water by movements.

SIERRA: Like waves or currents.

MOLLY BLOOM: That doesn't happen naturally in an aquarium, however, because there are no waves in an aquarium, no currents.

SIERRA: Allan Maguire takes care of the aquarium at the Minnesota Zoo. He explained how they keep aquariums friendly for the fish, sharks, and other animals.

ALLAN: The air that we all breathe dissolves in the top inch to inch and a half of water. And unless you move that water with the dissolved oxygen through your entire pool, the animals, and the bacteria, and everything that need oxygen in the water will not be able to get that oxygen.

If you have a small home aquarium, you've got a bubbler. People think that that puts oxygen in the water when, in fact, it does not. It simply moves that oxygen-rich surface water through all layers of your tank. In larger tanks such as we have here at the zoo, we have pumps. Pumps move the water from the bottom of the tank to the top of the tank or vise versa, taking that oxygen-rich surface water, mixing it throughout the entire pool to give the animals all the oxygen that they need.

MOLLY BLOOM: There are some places in oceans, lakes, and rivers where there is no oxygen.

SIERRA: These are called dead zones. Fish and other animals can't breathe in the dead zone.

MOLLY BLOOM: Here to tell us more is Nick Fash. He's an education specialist at the Santa Monica Pier Aquarium. Hi, Nick.

NICK FASH: How are you doing today?

MOLLY BLOOM: Well. Thank you for being here.

NICK FASH: Oh, my pleasure.

SIERRA: What is the easiest way and best way to explain a dead zone?

NICK FASH: A dead zone is any body of water that does not have enough oxygen to support life.

SIERRA: How do dead zones form in the ocean?

NICK FASH: Dead zones form whenever there is extra nutrients flowing into a certain body of water. The main nutrients that flow in is anything that a plant needs, or algae needs, or phytoplankton needs to grow. The primary ones are nitrates and phosphates. These come in, and they're the building blocks. That's the food for the plant and the algae. When it gets a lot of those, it's very happy and will grow and reproduce very quickly.

Unfortunately, they don't live as long as you and I. And those algae, that phytoplankton, will die. And that is what is broken down by bacteria in that same environment. So, imagine if you had a swimming pool and too much nutrients were flowing into it, that pool would then have too much algae growing in it. When that algae dies, it sinks to the bottom of that swimming pool where bacteria breaks it down and uses all the oxygen in that pool.

If you put a fish in there, would it be able to breathe?

SIERRA: No. About how many fish die in a dead zone?

NICK FASH: Well, that number can range from a few to many millions. It depends on where and how large that dead zone is, as well as what kind of life lives there in the first place. An animal like a fish can obviously try and swim away when it notices that it's having a hard time breathing. An animal like a clam, an oyster, or a mussel that can't move, they obviously are going to suffer and probably die because they can't breathe.

SIERRA: What is the biggest event that has happened in this area involving a dead zone?

NICK FASH: Two summers ago, we had a massive fish die-off down in King Harbor by Redondo Beach, the same place that you said that you went and found shells and seaweed and watched sea lions swim by. Unfortunately, there was a lot of nutrients in a body of water that was not moving very much. A lot of fish swam in there. And because of this algae decomposing with the bacteria, all the dissolved oxygen left that bay where we keep our boats, and the fish used up all the oxygen.

Frantically swimming around, trying to find a way out, they suffocated. And hundreds of hundreds of thousands of fish were floating, smelly on the surface of the ocean.

SIERRA: What are the main nutrients in dead zones?

NICK FASH: The main nutrients that flow into our waterways that create dead zones are nitrates and phosphates. A lot of these come from our farming, as well as things like our dishwashing detergent and detergents that we use to wash our cars.

Nutrients flows into our waterways in a few different methods. One way is it leaching out of the soil or it washes out of the soil when it rains from our fields and our farms. Another way is the water that falls out of the sky and lands on our streets and our sidewalks and the roofs of our homes. Anything that is left on our streets, whether that's dog poop, or a plastic bag, or some soap from you washing your car, is going to wash down that road through that hole you see on the side of the road known as the storm drain. And those storm drains all lead straight to the ocean or to the local river.

So by keeping our streets, and our cities, and our communities clean, what will also happen to our local waters and our local rivers?

SIERRA: They will be clean for us to swim in, to have fun in.

NICK FASH: And so that's something that you and all the listeners out there can do starting today to help keep our oceans and rivers clean so that these dead zones will hopefully be a thing of the past.

SIERRA: Thank you for teaching us about dead zones and how we can help clean up our ocean environment.

NICK FASH: Well, thank you very much. It was lovely to chat with you. I'm going to head back down to the beach. I think it's going to be a nice day out here.

SPEAKER 4: Ba, ba, ba, ba, ba, ba, ba, ba, ba, ba, ba, brains on.

MOLLY BLOOM: All right. The suspense is over. It's time to go back to the mystery sound.

[RUNNING WATER]

OK. So, Sierra already determined that there is water and that something's moving. But what exactly is moving? Do you have any guesses?

SIERRA: I think it might be the waves from the water drops moving back on the water. And maybe like an animal or us, a person, in the water doing some movement maybe?

MOLLY BLOOM: Hm-hm. You are getting very close with that animal idea. Here is Nick Phelps with the answer.

NICK PHELPS: The sound that you just heard was us feeding a whole bunch of goldfish. And In the background you probably heard running water. That was water coming back from a filter.

So the goldfish were part of a aquaponics system. Aquaponics is the production of fish and plants together in the same system. So we feed the goldfish, like you heard. And they're going to produce waste. And that waste is going to be the high nutrient-rich water that goes through the plant bed.

And those plants take up the nutrients like fertilizer. And the clean water comes back to the fish. So the plants are essentially the filter. Aquaponics is becoming very popular in urban metro areas as a way to produce local, sustainable, healthy food on a much smaller footprint than traditional agriculture.

MOLLY BLOOM: So, is that surprising to you?

SIERRA: Yeah, I thought it was probably someone splashing, maybe swimming in like a pool or the ocean. But fish can make that sound is surprising.

MOLLY BLOOM: Yeah, I was there when they were being fed. And all their little mouths were coming up and making that popping sound as they were trying to get the food.

So aquaponics is a system where there are tanks of fish connected to beds where plants like spinach, greens, other vegetables are being grown. There's actually some research connected to aquaponics that could possibly reverse or stop dead zones.

NICK PHELPS: It's the same theory that you could put plants out into the environment and they would absorb the nutrients from the water. And that's a lot of what causes that dead zone. If we could put plants in there, and the species of plants, different plants take up different amounts and types of nutrients. So there's a lot of research going on to the type of plants to use.

[MUSIC PLAYING]

SIERRA: Oxygen gets dissolved in the water from the air.

MOLLY BLOOM: Which is good because creatures living underwater need oxygen to survive.

SIERRA: Most animals absorb the oxygen through gills.

MOLLY BLOOM: But some can absorb it directly through their skin like jellyfish.

SIERRA: Some areas of water don't have oxygen.

MOLLY BLOOM: They're called dead zones.

SIERRA: They're caused when too many nutrients enter the ocean.

MOLLY BLOOM: But we can help prevent dead zones by using less fertilizer on our farms and gardens and stopping rain runoff from flowing out to sea. That's it for this episode of *Brains On!*

SIERRA: This episode was produced by Marc Sanchez, Sanden Totten, and Molly Bloom.

MOLLY BLOOM: Many thanks to Tanya Acosta Haro, Eric Ringham, Taylor Kaufman, Levi Petri, Jen Miller, Megan McCarty, Ariel Camp, Colin Campbell, Meg Martin, John Gordon, and Christopher Mah and Mike Vecchione from the Smithsonian Institute.

SIERRA: For more episodes and to see pictures of gills under a microscope, head to our website, brainson.org.

MOLLY BLOOM: While you're there, you can also subscribe to our newsletter to find out about new episodes and other fun stuff.

SIERRA: You can follow us on Instagram and Twitter at brains_on.

MOLLY BLOOM: And you can always send questions, mystery sounds, and high fives to hello@brainson.org.

And now, before we go, it's time for our moment of um.

SPEAKER 5: Um. Uh. Um. Um.

EDEN: Hello! My name is Eden. And I'm 6 years old.

TABITHA: Hi! My name is Tabitha, and I'm 8 years old.

BOTH: Our question is.

EDEN: Why do we have earwax?

TABITHA: And how do we get earwax?

KERRY: Earwax is perfectly normal and safe. My name is Kerry Witherell. I'm an audiologist at the University of Minnesota. Earwax acts as the first line of defense to protect our ears from unwanted things like dirt, dust, or bacteria.

Earwax generally is made up of dead or sloughed-off skin cells, and also oily secretions in our ear canal. Another benefit to earwax is that it is similar to tears in our eyes. So it will actually keep our ears lubricated. So if they weren't lubricated properly, our ears would always feel dry and itchy.

Earwax will also come out naturally on its own. So when we talk or chew, our jaw muscles help to keep the earwax slowly moving to the outer part of our ear, which will eventually work its way out. And we certainly don't want you to put things in your ears. So q-tips are the enemies of our ears. People might accidentally push the earwax further into the ear, making it hard for it to come out on its own. Or in the worst case scenario, you might cause some damage to your eardrum.

MOLLY BLOOM: Are your ears ready for this? It's time for the Brains Honor Roll. These are the excellent listeners who have sent us drawings, mystery sounds, questions, and ideas. Here they are.

[LISTING HONOR ROLL]

We'll be back soon with more answers to your questions.

SIERRA: Thanks for listening.

SPEAKER 4: Ba, ba, ba, ba, ba, ba, ba, ba, ba, ba, ba, ba, brains on.