GITANJALI RAO: You're listening to Brains On, where we're serious about being curious.

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

SPEAKER: There's a dimension just outside the reach of human knowledge-- a place of wonder and terror. Things may appear normal but look closer. You'll find peculiarities beyond your wildest imagination. It's a dimension we like to call the hydro zone. Imagine if you will, a substance that defies nature. A liquid that can crawl upwards against gravity. It's both sticky and slippery, hard and soft. It's able to cut through the hardest rock and yet still be moved by a gentle wind. What is this alien substance? A goo from a planet orbiting a distant star? A thing created in some lab? No.

It's just water. And speaking of-- [GULPING] [SIGHS] Magic see-through juice, I love you. Oh, aren't we all so lucky to be living in the hydro zone.

[MUSIC PLAYING]

MOLLY BLOOM: You're listening to Brains On from American Public Media. I'm Molly Bloom, and here with me again is 12-year-old Gitanjali Rao from Lone Tree Colorado. Hi Gitanjali.

GITANJALI RAO: Hi Molly.

MOLLY BLOOM: I think a lot of us take water for granted because it is everywhere. We use it and drink it every day, but when you take a closer look water is a weird substance. We'll get into the nitty gritty in a bit. First, but Gitanjali, I want to know what is your favorite thing about water.

GITANJALI RAO: I think water is just such a cool substance overall. One of my favorite things about it is the fact that we may be drinking the same water as dinosaurs.

MOLLY BLOOM: That is a really good fact. That is one of my favorites too. Is there anything about the way water behaves, like its properties that sort of gets you excited?

GITANJALI RAO: Yeah. So my favorite thing about water is probably-- I don't know-- it's just like, is water wet or does it make things wet?

MOLLY BLOOM: Whoa. That is an excellent question. So this is the second episode of an occasional water series that we're doing and our co-host Gitanjali is not only a fellow fan of the stuff, she also invented a device that tests the safety of water and it won her the Discovery Education 3M Young Scientist Challenge. Go Gitanjali. You can hear all about that in our first water episode called *What's in Your Water?*

GITANJALI RAO: We talk about the water cycle too. It's a fun ride.

MOLLY BLOOM: Now, it is no surprise that our smart and curious listeners have noticed some of water's strange behaviors and they've sent us some questions.

[MUSIC PLAYING]

BENNETT: My name is Bennett from Crawfordsville, Indiana. My question is, if water molecules are so strong, how come we can separate them with a hand?

TESS: My name is Tess.

EMMA: And my name is Emma.

TESS: We are from Walla Walla, Washington.

EMMA: Why does water flow and--

TESS: Why doesn't water stick together?

ED MICHAEL: I am Ed Michael from Baltimore, Maryland. Why does water hang for a tiny bit before it drops?

OLIVER: Hi Brains On, this is Oliver over from Holyoke, Massachusetts. Can you tell me why water expands when it freezes but nothing else does?

GITANJALI RAO: Man, so many mysteries. To help us explore the hows and whys of water's weirdness we called up Alok Jha.

MOLLY BLOOM: He's a science journalist who is so curious about water that he wrote an entire book about it. Naturally it's called *The Water Book.*

ALOK JHA: It became my mission then to make people just stop and just look at water slightly differently even for five minutes. Because I think we take it completely for granted, we think of it as dull when in fact, it is the reason that we're here. And isn't it bizarre that we don't understand so much about it?

MOLLY BLOOM: Here are some things we do know. Anything can be a gas, liquid, or solid. And as a substance changes from a gas to a liquid it becomes more dense. That means the building blocks it's made up of called molecules, they get packed tighter together.

GITANJALI RAO: Picture a park full of people wandering about, that's the gas. But then it gets cold so they all gather by the bandstand where there's less wind. Now they're closer together like the molecules in a liquid.

MOLLY BLOOM: Right. And when most substances go from a liquid to a solid, things get even denser.

GITANJALI RAO: So like imagine it gets even colder at the park. Now all those molecules people they're huddling close together. Now they're even more tightly packed.

MOLLY BLOOM: So that's what most substances do, but Alok says water is not most substances.

ALOK JHA: It freezes in a way that nothing else does. Everything else when it freezes, gets smaller or condenses, but water expands. And you know this because ice expands.

GITANJALI RAO: When most things freeze, they sink in the liquid version of themselves.

MOLLY BLOOM: Not water.

ALOK JHA: Ice floats in your drinks in the summer. We see icebergs floating on the seas. It's kind of obvious, but actually if you look carefully it's very, very strange.

MOLLY BLOOM: If the ocean was any other substance, that ice would sink. Instead it covers the surface of say a river or a lake and that ice layer ends up protecting the deeper parts from the cold.

SPEAKER: If water didn't do this, life wouldn't have made it through the ice ages since the oceans would have frozen solid. All the fishes would be fish sticks. Kaput, dunzo.

MOLLY BLOOM: But wait, there's more.

ALOK JHA: Another thing that it does, it can move upwards against the force of gravity. So water is a molecule-- a very simple molecule that likes to stick to things. And it doesn't like to stick to anything more than itself. So it sticks to itself. And so if you ever look at the surface of the water in a glass, you'll see that at the edges-- at the edges the water just curves up slightly as it sticks to the side of the glass because it likes to stick to things.

Now if you made that glass very, very, very, very narrow like a very thin tube then what would happen is that water could actually stick up the sides of that tube, up, up, up, up, up against the force of gravity. And actually that's how blood flows up from our hearts to the top of our brains. It's how water flows from the roots of a tree to the crown. Again, that's kind of a strange thing.

GITANJALI RAO: And a good thing too. If water didn't do this, us living things couldn't get very tall. There's a good chance life, if it existed at all, would be flat.

MOLLY BLOOM: Totally weird. But wait, water has yet another superpower.

GITANJALI RAO: It's good at breaking things down or being what's called a solvent. In fact, Alok says water is a superb solvent.

ALOK JHA: It will dissolve almost anything given enough time. Think about the Grand Canyon. These are hard rocks. And they've been carved through hundreds of thousands, millions of years of drip, drip, drip from water. And water has carved those enormous channels. So water is incredibly good at dissolving things.

MOLLY BLOOM: Wow. A humble glass of water can do so much.

GITANJALI RAO: Water's like a superhero. Is there anything it can't do?

[SIRENS]

MOLLY BLOOM: You hear that?

GITANJALI RAO: Oh-oh, sounds like trouble.

SPEAKER: What's the situation, Chief?

SPEAKER: Well, Mayor, it's like my breath in the morning, it's bad, real bad out there. We got ninjas on top of city hall threatening to take over the government if we don't give in to their demands.

SPEAKER: What are their demands?

SPEAKER: I don't even know where to start. They want $1,000,000 trillion, free bubblegum for life, light up sneakers, the Rock's autograph. I mean, the list goes on and on and on. The list is so long, that it is hanging all the way down from the top of the building to the ground. And the worst part is we've only got like five minutes to figure it out.

SPEAKER: Oh no, we're in hot water.

SPEAKER: Did somebody say water?

SPEAKER: Special Agent H2O!

SPEAKER: I hear you've got a ninja problem.

SPEAKER: I'll say.

SPEAKER: Well, they're about to have a water problem.

SPEAKER: Good to see you, but how are you going to get them? They're five stories up.

SPEAKER: You said there was a list of demands hanging from the roof to the ground?

SPEAKER: Yup.

SPEAKER: Well, water can climb up fibrous materials like paper. It's one of my amazing talents. Just splash me on the bottom of that list and my super agent hydrogen bonding skills will take over. I'll adhere to those paper fibers, and then to the fibers above that, and on and on up the list. Then once I'm up top, I'll flush those ninjas out with a geyser of justice.

SPEAKER: Brilliant! We're lucky to have you, H2O. Now get to it.

SPEAKER: It's bathtime, ninjas.

MOLLY BLOOM: So how is it water manages to do all these weird and wonderful things? Well, it comes down to chemistry.

GITANJALI RAO: Here to help us explore is brains on reporter John Lambert.

JOHN LAMBERT: Water's weirdness boils down to the forces that hold water together. Like everything, water is made up of atoms, those tiny building blocks that make up all the stuff in the universe. Now, atoms like to join together to form molecules. You've probably heard water called H2O before. That's because a water molecule is made up of two hydrogen atoms, that's the H2, and one oxygen atom, that's the O. Let's take a water molecule and name it Wally.

WALLY: Hey, guys.

JOHN LAMBERT: Wally has one big oxygen atom with two smaller hydrogen atoms attached. Picture something like a Mickey Mouse head with ears. That's Wally's shape.

WALLY: I'm tiny, which means I am also really cute.

JOHN LAMBERT: Now, every H2O molecule has an end with a positive charge and an end with a negative charge, just like a magnet does. The oxygen atom has a small negative charge, and the two hydrogen atoms have an even smaller positive charge. And like we talked about on our series on electricity, opposites attract. Positives and negatives are pulled together. So if you put Wally in a bucket of water.

WALLY: Cannonball!

JOHN LAMBERT: Wally's negatively charged oxygen atom would attract the positively charged hydrogen atoms of other water molecules. And Wally's hydrogen atoms would attract the oxygen atoms of still other molecules.

WALLY: So many new friends. This is awesome!

JOHN LAMBERT: These attractions are called hydrogen bonds. They're called that because they only form between hydrogen atoms and other charged molecules. These hydrogen bonds between different water molecules, between Wally and his new friends, are a lot weaker than the bonds that hold Wally himself together-- his oxygen atom and two hydrogen atoms. It's kind of like the difference between a firm, long lasting handshake.

WALLY: Ah, yes, official business.

JOHN LAMBERT: And a quick passing high five.

WALLY: Up top.

JOHN LAMBERT: Plus, hydrogen bonds exist for just a fraction of a second.

WALLY: 10 picoseconds to be exact. A picosecond is to one second what one second is to 31,700 years. So like, very short.

JOHN LAMBERT: So all these H2O molecules are zooming around, each high-fiving four neighbors at a time.

WALLY: Hello. To the side. Too slow!

JOHN LAMBERT: These small little extra bonds mean that water molecules can stick really well to each other, and it helps them stick to other stuff, like your hair. When your hair gets wet, that's just water molecules sticking to your hair molecules. But since these are also super quick bonds, remember, just a picosecond long, water molecules can also let go of other molecules quickly and keep on flowing.

WALLY: I like to say hi and then float on by.

JOHN LAMBERT: These hydrogen bonds even explain why water expands when it freezes. As water cools, these high five-like hydrogen bonds start lasting longer and longer until they finally freeze and stay put. This forces water molecules further apart from one another than when they were in their liquid state. Imagine each hydrogen bond is a sort of arm that Wally extends for high fives. When water freezes, each arm gets stuck, outstretched, leaving more room between the molecules and making ice less dense than liquid water.

WALLY: A forever high five? Now that's cool. Looks like we'll be here for a while, though. I hope my arm doesn't get tired. Brains On!

MOLLY BLOOM: Before we dive deeper into the mysterious depths of water, it's time for another mystery, the Mystery Sound.

SPEAKER: Mystery sound.

MOLLY BLOOM: Here it is.

[GURGLING NOISE]

Do you have any guesses about what that might be?

GITANJALI RAO: I think that it's rain on a gutter.

MOLLY BLOOM: Very excellent guess. Well, we're going to be back with the answer in just a bit.

SPEAKER: It's pandemonium downtown as evil genius, the Confectionista, is stomping through the streets in his giant sugar cube robot. He's punching holes through buildings like cavities punch through teeth. Joining me now with the latest is the chief of police. Chief, what's the plan?

Well, like my problem with excessive nose hair, I don't really have a solution. We're evacuating the area while we're trying to solve it.

Did somebody say solvent?

No, I said solve it.

Special Agent H2O?

Don't sweat this. Since water is a universal solvent, I can dissolve almost anything, given enough time. I even use rivers to carve out the Grand Canyon. So this sweet tooth terror doesn't stand a chance. I'll just soak his sugar bot and let my slightly charged water molecules break down the bonds of those sugar molecules. Give it a few seconds, then Confectionista sill be all washed up.

Amazing! Once again everybody, Special Agent H2O saves the day.

And the police chief helped.

No, she didn't.

MOLLY BLOOM: We'll continue our deep dive into water in a second, but first.

GITANJALI RAO: We're working on a series of episodes about the science of cooking, and we want to hear from you.

MOLLY BLOOM: If aliens came to Earth and you could only serve them one dish to introduce them to the food of our planet, what would you serve them and why? Gitanjali, what would you feed the aliens?

GITANJALI RAO: Pizza. It's a signature dish of the Earth.

MOLLY BLOOM: Exce-- so why do you think pizza is the signature dish of the Earth?

GITANJALI RAO: It has pretty much everything, sauce, cheese, bread. That's all you really need in life.

MOLLY BLOOM: I like it. So, listeners, tell us, what's your dish? Submit your ideas at BrainsOn.org/contact.

GITANJALI RAO: And while you're there, you can submit your questions, ideas, mystery sounds, drawings, and high fives.

MOLLY BLOOM: That's what Lucy did. She sent us this question.

LUCY: My question is, do fish have a sense of smell?

MOLLY BLOOM: We'll have an answer to that question during our Moment of Um at the end of the show, and we'll read the latest group of listeners to be added to the Brain's Honor Roll.

GITANJALI RAO: Stay tuned.

You're listening to Brains On from American Public Media. I'm Gitanjali Rao.

MOLLY BLOOM: And I'm Molly Bloom. Before we dive back into the water, let's get back to that mystery sound. We're going to hear it again.

[GURGLING NOISE]

OK. So after the second listen, do you have any new guesses?

GITANJALI RAO: No. I think I'm going to stick with my same answer.

MOLLY BLOOM: All right. Here's the answer.

MAX: Hi, I am Max from Evington, Virginia. That mystery sound was the water draining out of our big bathtub.

GITANJALI RAO: Oh.

MOLLY BLOOM: So you were right, there was water involved, but it was inside the house, not outside.

MAX: I love to sit and watch it drain out like a whirlpool after I take a bath.

(SINGING) B-B-B-B-B-B-B-B-B-B-B-Brains On.

MOLLY BLOOM: All right, we're back knee deep in this fast moving river of water amazingness.

GITANJALI RAO: Water is amazing.

MOLLY BLOOM: Now, you'd think that cold water would freeze faster, right? Because the temperature doesn't have to drop as far. It holds way more heat energy than you'd expect, which is what helps us keep our body temperatures so constant. After all, we're full of water ourselves.

GITANJALI RAO: And there's a bizarre phenomenon having to do with freezing water.

SPEAKER: Final call for the Freeze-a-thon Race. Final call! Contestants at the ready!

MOLLY BLOOM: So imagine you had a freezing race between a glass of cold water.

SPEAKER: It's me, cold water.

(SINGING) I said brrr, it's cold in here. It must be cold water in the atmosphere.

GITANJALI RAO: And a glass of hot water.

SPEAKER: Hey, y'all. It's never been so cool to be so hot.

MOLLY BLOOM: Now, you'd think that cold water would freeze faster, right? Because the temperature doesn't have to drop as far. But let's see what happens when we put them both in the freezer.

SPEAKER: Cold water is ready to chill out.

Hot is going to freeze with ease.

[CHATTERING]

MOLLY BLOOM: Now let's wait just a bit and.

SPEAKER: Whoa, whoa, whoa, whoa, cold water is not ready yet. Cold water is still slushy. Put me back in. Give me just another minute.

Oh yeah, that's right. I just want to say to all the haters out there who didn't believe a hot glass of water could freeze quickly, go back to school and learn about the Mpemba Effect.

Whoa, whoa, whoa. What? The Mpemba Effect?

MOLLY BLOOM: The Mpemba effect is named after Erasto Mpemba, a Tanzanian high school student who discovered this effect while making ice cream at his school back in the 1960s. He stuck his hot ice cream mixture in the freezer and found that it froze way faster than his classmates' cooler mixtures.

GITANJALI RAO: Erasto wasn't actually the first person to discover this. Scientists and philosophers have noticed this phenomenon for hundreds of years, but they still don't really understand why this happens. They have some ideas, though.

MOLLY BLOOM: Like maybe the hot water evaporates faster, leaving less liquid water that needs to be frozen. Or that the hot water has less stuff dissolved in it, and thus can super cool more quickly.

GITANJALI RAO: Either way, when you eat homemade ice cream fast, try freezing it when it's still hot.

MOLLY BLOOM: No time for an ice cream break now, though, because we've got a question from Alita to get to.

ALITA: I go to the park sometimes. And so I touched the water and it's moving, except for sometimes there's nothing touching the water. So is it alive or not?

MOLLY BLOOM: You might say no because, of course, water is just H2O, a chemical compound, a molecule. It's not itself alive.

GITANJALI RAO: But as we've seen, water does a lot of strange things that might make it seem lifelike, such as sticking together or climbing up stuff.

MOLLY BLOOM: And water is in all living things. It keeps us alive.

GITANJALI RAO: In fact, scientists think that water was a critical player in the origin of all life itself.

MOLLY BLOOM: On Earth, 3.8 billion years ago, there was water, lots of water.

GITANJALI RAO: And in that water where chemicals, the raw building blocks of life.

MOLLY BLOOM: But in order for life to get going, it needs an enclosed space.

GITANJALI RAO: Like a little bubble, or a cell.

MOLLY BLOOM: Right. A cell that can keep the good stuff in and the bad stuff out. Scientists think that because of water's amazing properties, it was a perfect place to form these early cell-like bubbles. That could have led to the first cells and, tada, pretty soon these cells could have led to living things.

GITANJALI RAO: Once those simple life forms got started in water, there was no going back. Even once life emerged from the seas to land, they still need water to function.

MOLLY BLOOM: And water wasn't just there at the start, it's playing a role in life every day. Here's Alok Jha again.

ALOK JHA: In our bodies, it does all sorts of interesting things. It moves energy in and out of our cells. It fills the gaps between inside the cell, it sort of dissolves lots of things so that other molecules can do their jobs. In fact, you can think of our whole bodies as water. All our cells are just bubbles of water with a few, little, tiny impurities in each one that makes them look a bit different and do something a bit different.

[MUSIC PLAYING]

SPEAKER: All right, officers, here's the situation. The aluminum factory is overheating and it's about to blow up and wipe out the nearby horsephanage.

Chief, quick question. Is that a--

Yes. Yes, it's an orphanage for horses.

Got it.

And like that huge ball of wax that is just stuck in my left ear, this is serious. But I have a plan.

Did somebody say amazing heat capacity?

[CHATTERING]

Not even close. Maybe you need your ears cleaned.

I have amazing heat capacity. That means it takes a lot of energy to heat me up, a little trivia for you, a kilogram of water can absorb over 10 times more heat energy than copper before warming up 1 degree Celsius. Way to lose your cool, copper, am I right?

Seriously, though, I was about to handle this.

So I'll just flood that factory and soak up all that nasty heat without breaking a sweat. Then the workers can get inside and turn off the dangerous machines. I'll save the factory. I'll save the horses. And you, kind citizens, can save your applause. I'm just doing my job.

[APPLAUSE]

No, seriously, you are the real heroes. I'm just two hydrogen atoms bonded to an oxygen atom.

I know one thing water can't do, be humble.

MOLLY BLOOM: I think we can all agree water is pretty special.

GITANJALI RAO: But part of what makes it so special also makes it vulnerable. It can easily soak up bad stuff, like lead and other pollutants.

MOLLY BLOOM: We talked about this in our previous water episode, and we learned one thing we can all do to keep our water safe, and that's get to know it better.

GITANJALI RAO: Become a Brains On water detective.

MOLLY BLOOM: We've partnered with Earth Echo, a nonprofit founded on the belief that kids have the power to change the planet. They run the Earth Echo Water Challenge, a worldwide initiative that equips kids with a fun and easy way to test their water.

GITANJALI RAO: You can test a lake or stream, for instance, and see if the water is too acidic or if it has too much dissolved oxygen in it. That's bad for animals living in there. Or maybe you'll learn your local watering hole is happy and healthy.

MOLLY BLOOM: To find out more about our project with Earth Echo, head to our website, BrainsOn.org, and find out how you can become a Brains On water detective.

[MUSIC PLAYING]

GITANJALI RAO: Water may seem kind of bland and boring, but it's actually a wonderfully weird thing.

MOLLY BLOOM: Its polarity and ability to form weak hydrogen bonds makes it a great universal solvent.

GITANJALI RAO: It can break things down, climb up other things, and when it freezes, it expands.

MOLLY BLOOM: Water is crucial for life as we know it.

GITANJALI RAO: But it can also be tainted by pollution and other human activities. So we need to do our part to keep our water healthy.

MOLLY BLOOM: That's it for this episode of Brains On.

GITANJALI RAO: Brains On is produced by Mark Sanchez, Sanden Totten, and Molly Bloom.

MOLLY BLOOM: This episode was produced by John Lambert, with help from Lauren Dee and Lauren Humpert. We had engineering help this week from Ted Coleman, Eric Stromstead, and Veronica Rodriguez. Special Thanks to Meg Martin, Kristine Hutchins, Amy Cole, Mary Plummer, Adrian Hill, Jed Kim, Leo Duran, Doug Gary, Jen Miller, Nick Roman, and [INAUDIBLE] Rao.

This episode is powered by the Water Main, a new initiative from American Public Media focused on connecting people to their water resources. Find out more at WaterMain.org.

GITANJALI RAO: If you have questions or mystery sounds to share, head to our website, BrainsOn.org. And don't forget to send in your drawing of Secret Agent Water.

MOLLY BLOOM: And Brains On is made possible in part by a grant from the National Science Foundation.

GITANJALI RAO: Now, before we go, it's time for a Moment of Um.

[UMMING]

LUCY: Hi, I'm Lucy. I'm 6 years old from DeWitt, Michigan. And my question is, do fish have a sense of smell?

ANDREW SIMONS: I'm Andrew Simons. I'm the curator of fishes in the Bell Museum of Natural History at the University of Minnesota.

Yes, fishes have a really good sense of smell. But what fishes can smell depends on the kind of fish. Some species will be specialized for smelling food. Some species can communicate essentially using their sense of smell. They can smell chemicals in the water that are related to where they live so they can navigate around and find their way home using their sense of smell. And they can tell if a member of the same species is ready to mate.

Fishes essentially have four nostrils, unlike us, we have two. And so on each side, water flows into the front nostrils and then out the back nostril, essentially. So the fish is constantly getting information about the environment as it moves through the water.

Other fishes have like little pumps under their skin so they can pump water into the nose. And that's sort of like the way we would walk into a room and just smell something funny and you'd sniff the room. Some of the fishes like eels can do this, and it's a similar process, except that they have this little pump underneath the nose that actively pumps water in and pumps water out.

Most places, the water is not really, really clear. Vision doesn't really give fish a long view on the world. But a sense of smell is great because it brings in chemical information that can drift in for miles. And so even if the water is really turbid or cloudy, the fish can use that sense of smell to find its way around and to find food. There's so much to know about fish. They're the coolest animals out there.

MOLLY BLOOM: What's that smell? Could it be the aroma of a new group of names ready to be added to the Brains Honor Roll? Yes. Yes, it is. These are the brilliant listeners who help us out by sending us their questions, ideas, mystery sounds, drawings, and high fives.

[LISTING HONOR ROLL]

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

(SINGING) B-B-B-B-B-B-B-B-B-B-B-Brains On.