But Why: A Podcast for Curious Kids

Where Does the Sky End?

May 8, 2020

[Jane] This is But Why: a Podcast for Curious Kids from Vermont Public Radio, I'm the host of this show, Jane Lindholm.

We take questions from curious kids all over the world and find interesting ways and people to answer them.

Today, we're going to get scientific, but also a little philosophical and imaginative. And we're going to do it with the help of a friend of mine named Zoe Keating. Zoe is a cellist. You might remember in one episode a long time ago, we learned a little bit about how stringed instruments like the cello make sound. So you might want to go back and listen to that episode after this. It's called Why Do People Like Different Types of music. In this episode Zoe is going to use her cello and her songwriting ability to help us feel our way through the episode as we listen.

I want you to look up wherever you are right now. Maybe you're in a car, maybe you're in your bedroom, or maybe you're outside or near a window and you can look up, up, up as far as the sky will go until your eyesight bumps into the clouds or just a barrier of blue.

And if you don't have sight or maybe it's dark where you are right now, I want you to just imagine what you think the sky might look like and see if you can kind of feel the air all around you.

[Matthias] Hi, my name is with Matthias. I'm 5 years old and I live in Durham, New Hampshire. My question is where is the border of the sky and outer space?

[Alesandra] I'm Alesandra and I'm from Bella Vista, Arkansas and I'm three years old, and I want to know why we can't hold air.

[Jane] What is the boundary between air and space? And why can't we hold air?

Air surrounds you. It envelops you. It reaches into your building, your car, your tent, your classroom. You breathe it in and you breathe it out. It spreads down to the ground and stretches as high as you can see up into the sky.

But if air is what the sky is made of and air is all around us, where does the sky begin?

Are we standing in the sky with our feet on the ground? And where does the sky end and space begin?

Now, you probably think you know where the sky begins because you can feel the land with your feet.

You can see the horizon where the land ends and the sky begins.

But sometimes that reality, we think is so clear can get turned upside down.

[Hugh] You know where the sky starts and whether London. I mean, I suppose physically there's a there's a place. But in practice, you know, when you're in a particular place, maybe it's not so clear. I don't know. It's not. And it changes depending on the conditions.

[Jane] That's Hugh Raffles. He's an anthropologist.

[Hugh] I'd say anthropology is the study of connections between people and other people and people and things in the world. I know that's about as general as you could be.

[Jane] One of the things cultural or social anthropologists do is they try to spend time in the place they're studying, talking to people about why and how they behave the way they do and what in their culture and landscape and history influences the way they live now. Hugh is in the process of finishing up a new book.

[Hugh] Book's sort of about rocks and stones, sort of. Not really but sort of.

[Jane] Rocks and stones and people. So as part of his research, Hugh went to a country called Greenland. It's a big island between North America and Europe. Part of it is above the Arctic Circle, the most northern part of the world, the top of the world, if you're looking at a globe. And Greenland is covered by a giant ice cap.

[Hugh] And it was in winter, well, it was sort of early spring. So it's very, very ice bound. Maybe it's a frozen bay. Everything was just completely frozen. So everything was white. There was really almost no gap between the land because the land was just covered in ice, between the land and the sky. You really couldn't tell where it was or what you but what you'd get instead would be these, these weird light effects like, you know, like sort of these, you know, like, oh, gosh, what are they called? A Fata morgana.

[Jane] A fata morgana is a mirage where the line between the air and the land, or the air and water seems distorted. Sometimes it can look like a boat is floating in the sky instead of the sea or like it's upside down. And the mirage can shift and change.

[Hugh] These different effects where the horizon sort of turns upside down or it creates these sort of like bubbles, or you get what looks like a row of skyscrapers on the horizon or something like this, you know, things that just very, very bizarre, bizarre effects. So you really have no idea where the sky where the sky starts. Even as you look up, it saw you start because the colors, the colors aren't really distinct. You know, it's it's just sort of like a shading.

[Jane] So at one point, while Hugh was in northwest Greenland, he had to take a helicopter ride up over the frozen ice to the place where he wanted to do his research.

[Hugh] And on the first, the first trip I made only got halfway over. Then the helicopter had to turn back. And it was because the the reflection from the iceman that the pilots couldn't tell where the sky ended and it was just all completely white. They couldn't they couldn't tell what was land, what was what the sky, because that sort of reflection back and forth between the sky and the sky and the ice was, you know, just made it basically the horizon just disappears completely. So you couldn't tell. So it was too dangerous for them to fly because they didn't know if they were just flying in to land. They couldn't tell. So I think. It's a good question? You know where the sky starts and where the land ends? I mean, I suppose physically there's a place but in practice. When you're in a particular place,

maybe it's not, it's not so clear. I don't know. It's not and it changes depending on conditions.

[Jane] Can you imagine what that would feel like to not be able to see the difference or understand the boundary between the sky and the earth?

[Hugh] Completely disorienting, completely disorienting and very, very interesting. Like a little unnerving, but very interesting. But yeah, it's definitely no no sky there sometimes.

[Jane] Now, of course, there's a difference between a rock and air, but so much of how we understand the world is how we perceive it, how it looks to us. Let's take what we know about the sky. The sky is technically the atmosphere above the surface of the earth. So when we're walking around, our heads are in the sky, we're breathing in the sky and breathing it out. And what is the sky or the atmosphere made out of?

[John] The atmosphere is the collection of all the air molecules and gases that we can breathe. And we won't move around in throughout the earth.

[Jane] That's John O'Meara. You've heard him before on this podcast. If you've listened to our episodes about space and planets and the Moon and the Big Bang. He's now the chief scientist at a big observatory in Hawaii called the Keck Observatory, where he and other astronomers study what the universe is made of, how stars and galaxies are formed and how black holes work. So John is saying that the atmosphere is all of these different molecules and gases, lots of nitrogen, oxygen and argon and other things like water vapor.

[John] An interesting thing about the atmosphere is that as you go higher and higher up, it gets less and less dense. What do I mean by that? So see, I took a jar and I was sitting in your house and I closed a jar and counted up the number of molecules of air in that jar.

And I get a really, really, really big number. And then I go on top of Mt. Everest, the tallest mountain on the surface of the planet. And I do the same experiment. I close off a jar with the air that's in it and I count all the air molecules. I still get a really, really big number, but I get a number that is smaller than the number that I got when you counted it at your house. And the reason is because as you go higher and higher up, there's less and less molecules of air in the atmosphere.

[Jane] We're going to come back to that because it's important when we start to think about where the sky ends and space begins. But that starts to give you some idea of what it's like as you go higher and higher into the sky. But what else is in the sky around us? Can you think of anything? Clouds. Yes, clouds are full of water vapor. And when the water molecules bumping around in the clouds start to bump into each other, they kind of hold hands or joined together and they become raindrops, which get heavy enough to fall to the ground as rain. And there are other things in the sky, too. They aren't made of sky, but they're in the sky. Planes and birds and particles of dust and dirt and also insects. Hugh Raffles, the anthropologist we were hearing from earlier, wrote a book all about insects. It's called Insectopedia. I read it a long time ago, but even years later, I often think about one of the stories he tells in it about how humans started to realize just how astonishingly many insects there are in the sky above us.

[Hugh] [Anywhere that we are, in fact, is just full of insects. But we don't know because we can't see them, because they're too small for us to see. But you'll find insects in the, you know, up to about 15,000 feet. And then you can find spiders at 15,000 feet. And if you're

over, say, a square mile of countryside, that could be up to, you know, 36 million insects per square mile.

[Jane] 36 million insects per square mile!

[Hugh] And it's not just like this sitting floating there. They're actually, they're actually going somewhere they're on the way somewhere. And some of them are just being, you know, the tiny and just being sort of blown up, blown about by the wind. But most of them probably, probably nearly all of them are actually going somewhere because they want to go somewhere. And it's hard to say whether they've got a good idea of where they're going, but they've left because they want to, they want to travel and they have ways of getting themselves down as well.

And they know that what direction they're going in, because they go up there to get caught in the winds and they know which way the wind is going to take them. So, you know, it's very hard to say, well, what does an insect know and how much does it plan things and that sort of thing. But well, you know, it looks like looks like some in some extent, they know what they're doing.

[Jane] Ladybugs at 6,000. Fruit flies and wingless ants, 4,000 feet up in the air, soaring on the wind alongside millions of other insects. Also heading out in search of food or habitat or fairer weather, or a mate, like ballooning spiders rising 15,000 feet into the air.

[Hugh] These spiders will position themselves and so that the wind is behind them or so. And then they would just like get blown up in a gust of air and taken up. And then they can sit at like angle themselves so they can catch the air and travel with the air currents.

You know, I think it's a little bit like, you know, the way that you will see birds, birds just sort of, you know, certainly in gliding, gliding in the air, on the currents and on a sort of upwelling of air. I think it's a little a little like that.

[Jane] In just a minute we'll get into that question about where air meets space.

This is But Why? I'm Jane Lindholm. And today we're exploring the sky and learning about some of the things that are in the sky that we can't even see, like insects. Humans started to learn about these millions of insects invisible in the air above us in the 1920s, when airplanes were still very new. They wanted to learn more about a kind of insect that was considered a pest because it killed cotton crops that were important to the economy in the American South.

[Hugh] And so they took these planes up with sticky traps and they ended underneath the wings to just try to capture some to get a sense of where they might be going and how many they were. They would fly to a certain height and open the traps for a little while and close them, then fly to another height and this kind of thing. And, you know, what they found was completely shocking. I mean, actually I think, I think they were horrified when they realized there were just thousands and thousands and thousands of insects at different, you know, at different levels and way, way higher than the obviously flying far further than they thought. So it was really an accidental discovery. You know, in that way as well, they're asking a very different question, I think, and then they found this phenomenon.

[Jane] In that spirit. I invite you to look up into the sky again and think about what you might find if you ask different questions or if you're open to the idea that your vision of the world may not explain everything that's actually happening. Like for Hugh, he now looks at the sky differently.

[Hugh] When I look into the up into the sky and it looks empty, well, it's not. But sometimes if you stand there and just keep looking and looking and looking eventually, as your eyes adjust you start to see things moving around.

You know that those are the low fly, obviously a very, very low flying things. But you start to be able to see them. Yeah, they'll just start coming into view. Your eyes will start to adjust to these like these little movements and you'll start to see hundreds of things moving around. And that just goes on. It's like, you know, like a column of air, just if you just keep looking up and up and up and up. It's just happening all the way to probably to about 15,000 feet. Yeah.

[Jane] Thank you to Hugh Raffles for helping us think about the sky in a new way. His book about insects is called Insectopedia, and he's a professor of anthropology at the New School in New York City. Now, you might be wondering if I've gotten so distracted thinking about insects that I've forgotten the very questions we're trying to answer. Well, fear not. We now know what air is. And I think we basically know the answer to Alesandra's question about why we can't hold it. We can't hold air because it's not solid. It's full of different gas molecules. And those gases are invisible and they float around us as we cut through them while we walk. Or if you try to grab them, they'll just slip through your fingers. But remember when John O'Meara used the example of capturing air or atmosphere in a jar? I suppose you could technically hold air that way. Catch it in a jar and put the lid on tight. Now, you probably can't actually twist the lid tight enough to prevent those air molecules from sneaking their way out. But let's pretend we could and you could tighten that jar up really tight and then keep it in your room. It would preserve that air even as all of the other air around you changes over time. Maybe you could save the air from a day that was really, really good and then open that jar up sometime when you're feeling blue or lonely and let it go and breathe it in. And remember that day when you were three and so happy before those air molecules blend into all the other air molecules all around you and disappear? And now what about Matthias and the question of the boundary between air and space? I hope by now you've gotten used to the idea that not all boundaries are quite what they seem. And so it is with sky and space. Here's astronomer John O'Meara again.

[John] I really like this question a lot for a number of reasons, but I think my favorite reason is that we don't have a good answer. Lots of different people tried to define where the sky stops or where the atmosphere stops and where space begins. And those people are usually people who try to send stuff up there like astronauts or rocket scientists who send spaceships up there or satellites and things like that.

[Jane] The atmosphere, remember, is the air all around us and it's made up of gases and vapor and filled with insects and other things. And it gets less dense as it goes up and up and up, the molecules get less close together.

[John] Now, what does that have to do with space? Well, if you keep going up, up and up and up and up, eventually you get so few molecules that you just kind of call it empty space or you just call it space. And so where is that defining line? Well, there's lots of different definitions.

I think the definition that's the most commonly used today is one called the Karman line. And this is a line that's based off of physics. So if you take an airplane and you fly an airplane through the air, you can ask how high up can you continue to fly their airplane, where the wings continue to provide lift, where the wings have the air pushing against them and you can hold the airplane up in the air. The von Karman line is the height at which there's not enough air to contribute to lift. If you put an airplane that high, it wouldn't fly anymore based off of the air and the lift on the wings. And that height is about 60 miles up, about 100 kilometers up. And that's only one definition of it. But it's the one that's used quite frequently now to define the boundary between regular air and space. The other one is one that international law uses. And international law uses one that says what is the lowest possible orbit that you could put a satellite in where the satellite would fly around without falling back to the earth because it was slowed down by the atmosphere, by the drag of the atmosphere. And so that's a different way of defining the boundary. That's one that's defined from space down instead of the earth up. And the third one is one that's based off of regions of the atmosphere, the region, the atmosphere closest to the surface of the earth is called the troposphere. That's where we live. That's where airplanes fly. And then above that is the stratosphere, which is where things like weather balloons and whatnot can fly. And then very far up is called the Mesosphere. It's still got atmosphere in it. And it goes up maybe to about eighty five kilometers, you know, about about 45, 50 miles. And then at about 100 kilometers up in what we call the thermosphere, is that Karman line.

That's also where the space station is, and most of the satellites that are orbiting the Earth that aren't in geosynchronous orbit are all in the thermosphere. And if you keep going up all the way up to about 700 kilometers, so maybe about 500 miles up, you get into what's called the exosphere, which is really almost empty space. But that Karman line is sitting there in the thermal sphere. And that's interesting to me because that's where the space station is and the astronauts in the space station. And there's still enough atmosphere there, even though we would all call that space. It's in the name space station. There's still enough atmosphere there to produce a little bit of drag on the space station. So every now and then, they have to boost the space station's orbit because the drag of the atmosphere is slowing it down just a little bit. Now, I know I didn't give you a really satisfying answer of what the boundary is between the sky and or the air and space. And it's really because we don't have a good answer. It's kind of a smooth boundary. It's not like a hard boundary. And it really depends on who's asking you, isn't it? Is it somebody trying to call themselves an astronaut? Well, they use either the von Karman line or they use a line that the Air Force and NASA picked back in the day about 50 miles up.

But what's really more important is to know that, you know, the there is this difference and that difference is the amount of air inside of a jar, what we call the density. And that's really the interesting thing. It's a great question and I thank you for asking.

[Jane] So even when it comes to the border between sky and space, the answer is different, depending on your perspective. Are you looking down from space into the atmosphere? Are you a rocket scientist trying to figure out how to get a satellite to orbit the Earth? Different definitions depending on how you look at it. And that seems like a good lesson for all of us to learn. The world looks different depending on how you look at it and what your life experiences are. So keep being curious and asking questions and trying to see things from a different angle. It might help us all get along a little better if we try to see things from other people's perspectives. We understand them better. But it's a benefit to you too, because looking at things from a different perspective gives you the opportunity to experience the world in amazing new ways. That's it for this episode.

I want to thank John O'Meara, chief scientist at the Keck Observatory, and Hugh Raffles, author of Insectopedia for sharing their knowledge and insight with us in this episode.

And to all of you for asking such great questions that make us think so deeply about the world around us and above us. Your questions make us adults more curious and open to new ideas. So thank you. I also want to give a giant thank you to Zoe Keating. You've been listening to her music throughout this episode. She created this music to help us feel what we were hearing and to understand it in a different way. You can find Zoe's music on her website, zoekeating.com. And we owe a fist bump to her son Alex, too, for helping offer a kid's perspective on where the music should go and what it should sound like.

He was 9 when he made his suggestions, but he'll probably already be 10 by the time you listen. But Why is produced at Vermont Public Radio by me, Jane Lindholm, and by Melody Bodette, our regular theme music is by Luke Reynolds. This theme music is by Zoe Keating. We'll be back in two weeks with an all new episode.

Until then, stay curious.