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00:06 Meagan Cantwell: Welcome to the Science Podcast for July 3rd, 2020. I'm Meagan Cantwell. First up this week, I speak with news intern Rodrigo Pérez Ortega about an Oasis of biodiversity in the Mexican desert. Next, we have researcher David Tatnell. He talks with host Sarah Crespi about a thermo acoustic speaker, a device that uses heat to create sound.

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00:31 MC: I'm here with news intern Rodrigo Pérez Ortega who is taking us to one of the most bio-diverse places in the world, Cuatro Ciénegas, a basin nestled in between the mountains of Northern Mexico. Thank you so much for joining me, Rodrigo.

00:45 Rodrigo Pérez Ortega: Thanks for inviting me, Meagan.

00:46 MC: Despite not being able to travel to Cuatro Ciénegas, you were still able to get a really good sense of place based on all of the maps, photos, videos and interviews with researchers. What exactly is this space then like?

01:00 RO: So imagine you arrive there in the middle of the desert and there's this butterfly-shaped basin. They call it a butterfly. It's basically, this valley that is cut in the middle with a mountain called San Marcos Sabina and that's what gives the butterfly shape. But also what's really interesting is you have all these pools. More than 300 pools of clear blue turquoise water and also rivers and lagoons. That's why it's called an oasis in the middle of the desert and all these pools are full of life. You have turtles, you have fish, you have crustaceans, plants, there used to be a lot of marshes there as well. Now, almost all the marshes are gone and some pools have dried up because of this water drainage, which we'll talk in a bit. But yeah, it just... I mean, every researcher I spoke told me, it's a magical place, it's a beautiful place, but it's also very important for research.

02:00 MC: Is there anything special about the water that's contributing to the biodiversity that's found in this area.

02:04 RO: Research on biodiversity goes back to the early 20th century when biologists came here and found this oasis in the middle of the desert. But little by little, they started realizing that the chemistry of these waters was unusual. It's very, very loaded on some minerals, like magnesium. But phosphorous for example, which is an essential element for life, you have it in your DNA, RNA. You use it to make proteins, you use this for energy. It's very low in these waters. So, you have all this, you would say imbalance for normal life, but yet you have all these animals, but more importantly, all these microbes, which at the time they didn't know. But there was some tell-tale signs that there were very interesting tiny life living there, which are Stromatolites. So these are structures, well bad bacteria, especially cyanobacteria make, which is like... They look like rocks, right? But they're actually sediment deposits or Carbonite, that these bacteria deposit over time and they're normally found as fossils. But these were alive. There was one researcher in particular called Wendell Minckley who had this hint of like, there must be something really interesting about the microbes here.

03:25 MC: He was initially focused more on the endemic vertebrates, right, like the fishes and the box turtle that you mentioned, but that's why he had to bring in another area of expertise to look at these microbes, and that's where one of the main characters in your story comes in.

03:42 RO: Yeah, it's kind of interesting how she tells the story, basically that NASA nabbed on her daughter. And Minckley wasn't an expert on microbes or anything like that. Right about at that time in the late '90s, the NASA Astrobiology Institute was born. So he had this plan of, "Okay, let's study this as an Astrobiology site." And that's when they recruited this Mexican couple Valeria Souza Saldivar and Luis Eguiarte Fruns and they were the ones like nearly minted professors at UNAM, the National Autonomous University of Mexico who are experts on this microbial ecology, which was a new field at the time. They saw the potential of this place and they jumped right in.

04:27 MC: They've been studying the area ever since, almost for two decades now. They've published so many different papers about the crazy microbes that live here. What are the kind of insights they've gained into early earth from their studies throughout the area?

04:41 RO: The main question for them was these microbes, why are there so many and why are they so diverse? So how to study, not how life originated, but how it diversified over years. They still had these hunch of like, "Oh, these are the conditions of this unbalanced chemistry. It is the same chemistry as ancient seas. So it made sense that a lot of these microbes are descendants of ancient sea mite groups. In a paper in 2006, they published the first microbial ecology paper from Mexico. They could pinpoint that more than half of these microbes were very closely related to marine microbes and as much as 10% of them were similar to microbes only found in hydrothermal vents deep in the ocean. So that was kind of like the first clue like, "Okay, these microbes could have been direct descendants from an ancient ancestor from more than 300 million years ago."

05:44 MC: This area is not always been a desert, it was likely near an ocean, a sea, millions and millions, hundreds of millions of years ago.

05:52 RO: By looking at the DNA from the microbes, they figured out there was two ways that the microbes got in here. So one is when the Super continent Virginia broke off about 655 million years ago. And the second way of colonization was when Pangaea also broke off. This desert was a sea and then of course with the uplift of the mountains and tectonics, the sea retreated. But all the chemistry to sediments and the microbes stayed there. So of course, the water is not the original water, right? It's probably coming from the ice ages, because this is fresh water, but basically, it's holding all these sediments and all these elements, and then sustaining this ancient life.

06:38 MC: There are definitely so many different discoveries they've made here, but pretty much throughout the duration of them studying this area, they've also come up with a lot of different hurdles, mainly that canals have been draining these pools and using them to irrigate crops for agriculture. How exactly has this impacted the area?

06:56 RO: Well, it has impacted it a lot. So this is even before Valeria and her husband Luis, started researching this place. And Minckley was the one who first raised the alarm by seeing all this drainage of the waters. It's a desert, but it's also a region known for cattle and dairy and all these cows need to eat something. So they use this water to grow Alfalfa which is very water-intensive. Since the 1970s, they're draining the water to even take it out of the basin and going more than 80 kilometers away to irrigate these Alfalfa fields. So over the years, these researchers have been using older findings to say, "Hey, this is very valuable as a scientific place, but also this heritage from Mexico, and it's not worth it to take this water out."

07:52 MC: Since they've been draining it since the 1970s, it's not just a hypothetical of, "Oh, it might eventually impact these pools," but some of them have been completely drained and have been dry for years.

08:03 RO: Right, so there's this pozo called El Churince on the western part. And this place is very special because of the chemistry, what was going on. They actually got a grant to allow the researchers to study this pool. They studied as much as they could. Valeria told me more than a 100 scientists from Mexico studied the place. More than 50 papers came out of those five years of research, which is impressive. She told me it's one of the most studied place on Earth, right, and then it dried out right after the grant ended in 2015, 2016, the pozo had dried up. And you could hear it when I was doing all these interviews, the researchers, their voices broke, there were some tears, kinda indicating, they were really lamenting that this place dried up.

08:52 MC: A lot of local people also started joining in to that research. There are just local scientists now who are also wanting to preserve this area and advocate for it and get more involved in research.

09:04 RO: Yeah, exactly. So in the early 2000s, Valeria saw a lot of potential in this place. Her strategy was, "Well, I mean, let's involve the community." She started involving the local high school students on research. They were helping her take samples, she was explaining all the science. She would give all these workshops on molecular biology. One of the students went on to do a PhD in Biotechnology, and now he went back to Cuatro Ciénegas, and he's in charge of this mega project that is aiming to build a scientific museum in the village of Cuatro Ciénegas and also trying to push for Cuatro Ciénegas to be a scientific tourism destination worldwide. There's a lot of potential and it's also great to see the local people being interested in science, but also appreciating the value of this place.

10:02 MC: Right. And with Valeria and the community working together, they were able to get a promise that one of the major canals that's carrying this water is going to be shut down. As soon as the pandemic will allow it, it'll be shut down. Now that it's likely that these remaining pools are going to persist for some amount of time, what's next for research in this area? What are they looking forward to investigating now?

10:25 RO: They are now very interested in Archaea, which is a very special branch of life, which are these microbes which are not bacteria, but also known as Eukaryotes. They are kind of in the middle. They were first found in the deep ocean. The number and the diversities is much smaller than for bacteria. I think last year, they found this place, that they now called Archaean Domes which was semi-dried, so it was... Well, because it had rain and they saw these bacterial mats that they were floating very alien-like. If you look at the pictures, it's very interesting how it is. They are white, but when you cut through them, there's all these layers of bacteria. And they found a lot of Archaea there, more than, I think, 230 species, different species. And they claim that this is the most diverse place in Archaea. Only in 1.5 meter, they could find this diversity of Archaea. Which is in agreement with the rest of... It's one of the more biodiverse place in terms of microbes in the world. And now they are after this very special type of Archaea which are called Asgard Archaea. So these were, again, normally found in hydrothermal vents deep in the ocean, and they are thought to be this step from, evolutionally speaking, from prokaryotes to eukaryotes, which is really interesting. You never know, they might find something also new in terms of evolution of life there.

12:01 MC: It's definitely an amazing place. Thank you so much for speaking with me, Rodrigo.

12:04 RO: Yeah, you're welcome. Thanks for the interest.

12:06 MC: Rodrigo Perez Ortega is the news intern for Science. You can find a link to his feature at sciencemag.org/podcasts. Stay tuned for an interview with David Tatnell about speakers made from heated thin films.

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12:24 Sarah Crespi: The sound of thunder comes from a sudden change in temperature and pressure, this creates shock waves, and as an example of thermo acoustics, David Tatnell and colleagues write in Science Advances this week about making a thermo-acoustic device by heating thin films to make sound. Hi, David.

12:44 David Tatnell: Hello.

12:45 SC: So I started with the example of thunder, are there other examples of thermo-acoustic sounds in nature?

12:52 DT: So another example is the Bombardier beetle. They're quite renowned for making a distinct popping noise, which is due to an exothermic reaction within their abdomen.

13:01 SC: So they make a little bit of heat and it causes that popping noise?

13:04 DT: Yeah.

13:05 SC: And the device that you made for this paper operates on similar principles, what's making this sound exactly?

13:12 DT: The way we're heating our device is electrically. So similar to how your kettle works or a light bulb produces heat, which is driving a current through the device, and just due to its resistance, you'll get some heat given off. If we turn the power on and off very quickly, you can heat your device on and off.

13:29 SC: Sound is waves, so where do the waves come from?

13:32 DT: You heat the device as some of that heat will go to the air and that kind of acts as like a piston of air, because your air pressure increases around the surface of your device, and that pushes any surrounding air away from it. So with each heating of the device, it acts as a pulse which pushes any nearby air away, and when you're doing this repeatedly you get a sound wave.

13:56 SC: How fast are you doing this?

13:58 DT: We are typically working in the ultrasound regime, so this is, say, 50,000 times a second.

14:03 SC: Is this why you couldn't share any audio samples with me?

14:07 DT: Yeah.

14:08 SC: I was very excited to play a sound from this device, but it's not something that we humans can hear, huh?

14:14 DT: Not typically, 'cause they're more efficient in the ultrasound regime.

14:19 SC: Why were you doing this? Why create a device that uses electricity to make heat, to make sound?

14:25 DT: We were interested in creating ultrasound arrays for doing lots of different things, such as steering a beam or producing some interesting sound pattern. Typically, speakers use mechanical movements, you'd have some vibrating plate that just pushes the air about. This has some problems. For instance, if you've got very small array, so you've got lots of little mechanical speakers next to each other and they're all moving in their own separate way, these mechanical vibrations of each of these speakers will tend to talk to each other, 'cause mechanical speaker also acts as a microphone. So each speaker will be picking up the sound coming from all of the other speakers nearby. So you get a lot of crosstalk with traditional arrays, which gets worse as you decrease the size of the array. But with our sound sources based on heat, the generation of sound is one way predominantly, so they only act as a speaker and not as a microphone.

15:24 SC: Okay, so one of the advantages of making sound this way is that you don't get crosstalk, you're not thinking a microphone and a speaker at the same time. What about its size, is it something that you can scale down quite a bit?

15:36 DT: Yeah, if you've got a mechanical speaker, you've got moving parts, which as you decrease the size of your device, it becomes increasingly tricky and expensive to make. In contrast, our speakers, they're very easy to fabricate, so it's just thin film deposition and you can easily pattern it using standard lithography techniques. This allows us to go much smaller.

16:00 SC: How big is this device that you worked on?

16:03 DT: We're working in the millimeter range predominantly, so we have 1 centimeter chip. The smallest feature size we got down to was about 25 microns, which is about as small as you can get at the moment mechanically, and we still get a decent amount of sound out of that.

16:21 SC: So a mechanical speaker that size, 25 microns, is that something that I could hear?

16:27 DT: You would be able to hear that.

16:28 SC: What? And you're saying that you could get even smaller with this new technology?

16:33 DT: Yeah. With ours, theoretically, you can basically go as small as you want, as long as you can fabricate it and your material can handle the heat as it were. It's obviously the smaller you make it, the more power you're putting through a thinner wire.

16:47 SC: This is ultrasound. Is this something that you can go to lower frequency, so you can make sounds that people can hear, that can be used in devices that we depend on for sound, like phones, computers, TVs, stuff like that?

17:01 DT: Yeah, the devices do work in lower frequencies and they've got very broadband response because you've not got these mechanical parts, you don't get the typical mechanical resonances, so it works very strongly at specific frequencies. It is quite broadband in that respect. But they definitely work at lower frequencies. We have tried them and they work just as well, you just need to supply a bit more power. But there's possibly other techniques to pull out lower frequencies.

17:32 SC: What kind of uses do you see for this device in the ultrasound range?

17:37 DT: Things such as non-destructive evaluation. So for instance, if you've got a piece of metal, you might want to inspect that for any defects. And one way of doing this is to take an ultrasound array, and use that to acoustically scan your sample and any kind of inconsistencies within the material such as a crack. And they will scatter some of that sound back, which you can pick up.

18:01 SC: So like an ultrasound?

18:02 DT: Yeah. Yeah, exactly that.

18:03 SC: What other applications do you see for this device?

18:06 DT: So a more recent thing that's getting some traction with ultrasound arrays is acoustic levitation. So if you have an acoustic array, you can actually lift small objects using just the sound alone. At the moment it's very small things, such as beads, for instance. But they can be used to make interesting things such as you could have a volumetric display, for instance, where you've got a bead and you move it around in 3D to draw an image, for instance.

18:35 SC: Why would this approach be an improvement on the current kinds of speakers being used for acoustic levitation?

18:42 DT: The typical ones, they have all this crosstalk due to the mechanical movement of the speakers. And when you're applying many different phases and signals through each of the speakers, it starts to get a bit messy. The degree of control you have with the array is somewhat diminished with our arrays, because we've not got the crosstalk it has high potential for greater control.

19:07 SC: So is that the direction that you're gonna go next, trying to optimize the materials to get it smaller, or are you looking to get more precision in controlling levitating objects from an array?

19:21 DT: So we've got a few different directions. But yeah, definitely at the moment, increasing the efficiency of the device, is somewhat of an aim, 'cause at the moment they're still considerably quieter than a mechanical speaker for the same amount of power supplied to optimize the efficiency if this comes down to kind of fabrication, so choice of materials, for instance, and what kind of material you're mounting your device on. 'Cause you want to maximize the amount of heat that's being transferred from your electrical film to the air, and you don't want any of it, say for instance, going into a glass slide that you've deposited it on.

20:00 SC: Thank you so much, David.

20:00 DT: Thank you, too.

20:01 SC: David Tatnell is a post-graduate researcher at the University of Exeter. You can find a link to his science advances paper at sciencemag.org/podcasts.

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20:12 MC: And that concludes this edition of the Science Podcast. If you have any comments or suggestions for the show, write to us at sciencepodcast@aaas.org. You can listen to the show on the Science website, that's sciencemag.org/podcasts. There, you will find links to the research and news discussed in the episode. And of course, you can subscribe to the podcast anywhere you get your podcasts. This show was edited and produced by Sarah Crespi and Meagan Cantwell, with production help from Podigy and Joel Goldberg. Jeffrey Cook composed the music. On behalf of Science Magazine, and it's publisher, AAAS, thanks for joining us.