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00:06 Sarah Crespi: Welcome to the Science Podcast for October 26, 2018. I'm Sarah Crespi. In this week's show, Meagan Cantwell talks with reporter Julia Rosen about a group of kids suing the US government to try to stop climate change. And I talked to Andrew Moeller about a long-term experiment tracing the transmission of microbes from one generation of mice to the next. And for our monthly book segment, Jen Golbeck interviews David Lazer about his book Politics with the People: Building a Directly Representative Democracy.

00:40 Meagan Cantwell: I'm with Julia Rosen to discuss an historic case hitting the Federal District Court in a week. 21 youth plaintiffs filed a suit against the US government alleging that they have contributed to climate change and failed to protect natural resources as a trust for future generations. Hey, Julia.

00:57 Julia Rosen: Hey, how's it going?

00:58 MC: Going well. So could you give a little background on how this lawsuit got started?

01:02 JR: Yeah. So this lawsuit was first filed in 2015. So at the time it was filed against the Obama administration. And it's based on kind of this interesting legal theory that was developed by a law professor at the University of Oregon called Atmospheric Trust. The government sort of in its contract with citizens is responsible for protecting various natural resources as public trust. And so this argument is that the atmosphere and a stable climate, that those are things that the government is responsible for protecting. So the plaintiffs here are mostly young people, as well as the climate scientist James Hansen. They allege that the government has taken actions that have promoted and enabled the extraction, transportation and use of fossil fuels which have produced greenhouse gas emissions, which have led to climate change, and so they haven't protected this atmosphere as public trust.

02:01 MC: What are the plaintiffs alleging exactly is the amendment or right that is being violated by these government policies?

02:08 JR: This has changed a little bit over the last few days as there's been a bunch of legal motions and the run-up to the trial. But basically they alleged that their right to life, liberty, and property is at risk here because of climate change.

02:21 MC: So, who are these plaintiffs? Could you give some examples for how they claim that climate change has impacted their lives?

02:27 JR: There are a bunch of youth plaintiffs. They live in Oregon, Colorado, Louisiana, Florida, Arizona, all over. And they have experienced the effects of climate change in many different ways. So a lot of them have been impacted by extreme weather events that scientists say can be

exacerbated by climate change. So several of them have experienced severe flooding, drought. There is also a health impact. So some of the plaintiffs have asthma and say that when you have a big wildfire and there's smoke that that aggravates their asthma, many of them say that they experience psychological distress thinking about climate change and their future as young people growing up in a world that will be altered as well as losing the ability to recreate in places that will be affected by climate change. So there's really quite a range of impacts that have been raised in this case. But they all relate to these, seeing their future being strongly affected by climate change.

03:25 MC: Based off of court documents and testimonies, you wrote that you don't expect the government will challenge that humans have induced global warming. So what do you think will be the make or break questions in this trial?

03:36 JR: What it seems like the trial may come down to is the government is challenging that the youth have standing to bring this case. And to have standing in federal court, the plaintiffs have to show that they have suffered harm or injuries because of the actions of the defendants. And so they have to sort of trace this causal chain of events saying that the actions of the government contributed to the injuries that they suffered.

04:04 JR: And as I mentioned earlier, a lot of the injuries came because of extreme weather events. And so one of the areas of contention is going to be, "Can you say that those extreme weather events were made worse by climate change?" And this has been an area of active research for many, many years. And for a long time, scientists said climate change will increase the frequency of extreme events, but they hesitated to say this particular extreme event is due to climate change. But in recent years, there's been a lot of development in this area which is called attribution science. And now there is really a lot more evidence that you can analyze an individual event and say whether or not it was exacerbated by climate change.

04:43 MC: So what approach are the scientists as defined for the plaintiffs taking to support claims that extreme weather actually is tied to climate change?

04:51 JR: So in this particular case, the plaintiffs have brought on Kevin Trenberth who's a climate scientist at NCAR and he has a method of doing this attribution that sort of says, "Look, we know for instance that warmer air holds more water, and so we know that climate change has made the rainfall in a specific event X amount worse." And so that's the argument that they're putting forward.

05:12 MC: What do you think will be the defense's counter-argument to that?

05:15 JR: The government has brought on another expert who says we can't really draw this connection for these events. And so I think one of the areas that will come up is whether you can really draw this causal chain between climate change and the extreme events that affected the plaintiffs.

05:29 MC: Another debate you mentioned is also how climate change has impacted the health of these plaintiffs. So is it gonna play out similarly with this debate as well?

05:37 JR: There's a very similar argument that will take place probably around the health impacts. Like can you say that this person's asthma attack was caused by smoke from a wildfire that was made worse by climate change.

05:49 MC: And the outcome that the plaintiffs want isn't necessarily money, but more so the lowering of greenhouse gas emissions.

05:55 JR: Right. So that's really important. And that's actually also part of this standing argument. To bring a case in federal court, it has to be an issue that the court can actually remedy. They're not asking for money. They're asking for the judge to order the government to come up with a plan that they say will bring it back into constitutional compliance so it will stop violating their rights. And that will include massively reducing greenhouse gas emissions, phasing out fossil fuels, lowering greenhouse gas concentrations, the atmosphere, and basically coming up with a plan to stabilize climate.

06:29 JR: And so they don't have to say, "Here's exactly how you should do it," but they have to say it's possible. Because the judge can't order the government to do the impossible. So they have submitted several expert testimonies from energy experts who have done work in the peer review literature saying here are some ways that we could rapidly decarbonize the US economy. And again, the government has submitted expert reports of people saying these plans are unrealistic. It's gonna be more expensive than this. It's not this easy technically. So there's a whole set of scientific and research questions around the remedy.

07:03 MC: So what is the goal for the plaintiffs in terms of these greenhouse gas emissions? What's the level that they say is within constitutional limits?

07:11 JR: They have said that a safe level would be 350 parts per million. So today it's about 410. And it's just worth noting that that is a lot more aggressive of a goal than what, for instance, the Paris Climate Agreement has set. So that would be quite a tall order for the entire world, not just the US.

07:30 MC: Right. And within this lawsuit, do they have any sort of time frame that they propose that they would want this implemented by?

07:36 JR: They do say that they would like it to be 350 by the end of this century. But the judge has discretion in that area. So the judge can rule for them and still set a different target.

07:48 MC: How do people think enforcement will look like if the judge did rule in the plaintiff's favor?

07:53 JR: The government has consistently made the case that this is not a question for the courts. The question of climate policy should be one that is decided by lawmakers. So they're arguing that if the plaintiffs were to get what they want, the judge in Oregon, Judge Ann Aiken, would basically become the carbon regulator. They say that's really not the way that we should do this. But the

plaintiffs called the court their "last resort". And so they see this as an effective way of making progress and that there are legal experts who say that the EPA in their view does have broad authority to regulate carbon emissions. The judge can't order Congress to pass a law, but the judge can order government agencies to do certain things.

08:36 MC: And both the Obama and Trump administration, you mentioned, have tried to stop this case from going to trial. And that happened again this past Friday when the US Supreme Court granted a stay in this trial. And they're now waiting a response from the plaintiffs. So what do you think is the likelihood that this case just might be completely dismissed?

08:53 JR: The government's argument is that this would just be a huge investment of time and money for them for a case that they don't feel has legal basis. But the plaintiffs obviously are arguing that the case deserves to be heard after all this time. We'll all just have to wait and see.

09:08 MC: Do you have any sense for how this ruling may turn out?

09:12 JR: I don't know. All I have been told is that no matter which way it goes, it's going to be appealed.

[chuckle]

09:18 MC: Okay.

09:18 JR: And that, in many ways, this trial may be the one in which science plays the biggest role. And when it goes to a higher court for appeal, the legal questions about whether the youth have standing and whether we wanna set climate policy through the courts, are likely to be more important.

09:34 MC: Thanks so much, Julia.

09:35 JR: Yeah, you're welcome.

09:37 MC: Julia Rosen is a science journalist based in Portland, Oregon. You can find a link to her story at sciencemag.org/podcasts.

09:45 SC: Stay tuned for my interview with Andrew Moeller on watching gut microbes get passed down from one generation to the next.

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09:57 SC: This episode is brought you in part by the NSA. Almost every day, we hear something on the news about a cyber attack. Sometimes it's just a bunch of pranksters, but more often it's a foreign country with vast cyber resources trying to hack the power grid, the banking systems, or the military's information networks. The National Security Agency plays a big part in protecting our country from cyber attacks, and you can help. The NSA is hiring technical professionals to serve on

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11:04 SC: Now we have Andy Moeller. He's here to talk with us about a long-term experiment tracing the transmission of gut microbes from one generation of mice to the next. Hi, Andy.

11:14 Andrew Moeller: Hi.

11:14 SC: This is a nice big study, lots of mice over lots of time. And you're looking at both vertical transmission from parents to offspring and also at horizontal transmission. So how do these microbes move through the environment from one mouse to another mouse? Let's start with the mice that you used. You got them from the wild. Why did you do that?

11:38 AM: The great thing about these mice is that there's a tremendous amount of variation in the gut microbiomes of wild mice that we don't see in lab mice. And so we went into the wild to capture an immense variation in the gut microbiome, and we caught 17 pairs of mice from wild populations, one population in Edmonton in Canada, and then the other in Tucson, Arizona in the United States. So we took these wild-caught founders, brought them into the lab, and in-bred them through sibling matings for around 10 generations.

12:11 SC: Wow, that's a long time.

12:13 AM: Yeah, it took several years. It's a huge effort, and I think these lines are gonna be useful for a lot of different research questions. And so if you're inbreeding the mice in the lab in a controlled setting, they're all in the same room eating the same diet, we could watch from generation to generation the composition of the gut microbiome and make very strong inferences about microbial transmission from this experiment because we've controlled for so much environmental variation.

12:38 SC: How does a parent mouse pass down their gut microbe to their offspring?

12:45 AM: The initial exposure to microbes comes during the birth process. So through the vaginal canal, newborns get exposed to microbes right away. But mice and rodents are special in this sense because they're coprophagic. So they actually eat the feces of their cage mates.

13:00 SC: Well, there you go. That's one way of getting it in the hair.

13:03 AM: Yes. So that provides a really clear route for vertical transmission between mother and

offspring.

13:08 SC: When you say you control the environment, how do you know when things were going from parent to child rather than being in the same room or interacting with the same people?

13:19 AM: So yeah. So that was actually something we were interested in looking at. So we were interested in looking across the entire microbiome and asking the question how are different groups of bacteria transmitted. Is it just random or they all have the same probability of being either vertically or horizontally transmitted, or do certain groups favor vertical transmission or horizontal transmission? And so we allowed for horizontal transmission through the indoor environment, through animal handlers, through the air, through a contact with the common surface, for instance. By not controlling for the possibility of horizontal transmission, it allowed us the opportunity to actually study horizontal transmission and to identify gut bacteria that seemed to be transmitted horizontally more often than vertically.

14:03 SC: How were you able to pick that out of the data if you weren't isolating them? What did you have to do to say, "Well, this one came vertically and this one came horizontally."

14:12 AM: Right. So we have these 17 different mouse lines in the lab, and we collected the gut contents from each generation, and then we sequenced the DNA from those samples, and that allowed us to identify all the bacterial lineages or the vast majority of the bacterial lineages present in each mouse from each generation from each line. And then we could simply look bacterium by bacterium or bacterial genus by bacterial genus and ask whether members of that bacterial group tended to be shared more often by mice from the same line or more often by mice from different lines.

14:46 SC: So you would say, "Oh, well do their parents have it?"

14:49 AM: Not just their parents. We'd actually look throughout the lineage or genealogy, the inbred line and ask did the parental generation have this certain bacterial lineage, but did the grandparents, the great-grandparents, all the way back to the beginning of this experiment.

15:04 SC: They were distinct enough at the start?

15:05 AM: Yeah. So that was the key is that each wild-caught pair had a distinct individual microbiota which is what we see in all mammals essentially. So, all humans have a unique signature.

15:15 SC: So you could see those signatures all the way down through all these generations.

15:19 AM: Yeah. We were surprised to see that the individual level variation that was present at the beginning of this experiment was maintained all the way to the end with an inbred mouse line. So the 10th generation descendant of a wild-caught mouse harbored a gut microbiota that looked very similar to its great, great, great, great 10 times parent.

15:41 SC: [chuckle] You cannot answer this question, but it just immediately makes me think if there's any possibility that what's in my gut is what my 10th generation ancestor's gut was like.

15:51 AM: Well, it's very possible. Yeah. So we've found in some previous work that if you build evolutionary trees from gut bacteria from humans, chimpanzees and gorillas, the evolutionary trees of the gut bacteria mirror the evolutionary trees of the host species. And so it's likely that each human does have bacteria from their great-great-great-grandparents still floating around inside of them.

16:13 SC: That is so cool.

16:14 AM: Yeah.

16:15 SC: I really like this idea that you bring forward of fidelity. We pass our genes down and our offspring have some of that. It's indelibly recorded in them. And this sounds like it's also happening with our bacteria, our microbes.

16:30 AM: Yeah. So admittedly our situation, or our laboratory setup, is probably favoring vertical transmission.

16:38 SC: Right.

16:38 AM: It's definitely favoring vertical transmission more than a real world setting because the mice never come into contact. So mice from one line never come into direct contact with mice from a different line. And so we and other people have also shown in apes, we've looked at this in chimpanzees and other people have looked at this in baboons, that social interactions allow the transmission of gut bacteria too. So for this paper, we didn't allow contact between the lines. So in that sense, we're favoring vertical transmission.

17:05 SC: Yeah. And inbreeding them also would do that too.

17:07 AM: Exactly, yeah. And the experiment was designed well to identify bacteria that can be horizontally transmitted in the absence of direct contact, things that could be transmitted through the air, for instance, or through a vector like an animal handler.

17:21 SC: And what did you learn about those particular bacteria, the ones that were coming into these mice on this horizontal route?

17:27 AM: One thing that jumped out right away was that more closely related gut bacteria tended to be more similar in their transmission strategy.

17:34 SC: Okay.

17:35 AM: At least for some parts of the bacterial phylogeny. That's interesting 'cause it suggests that there are some traits that are evolutionarily conserved that determine transmission mode for

bacteria. So that opens up some questions about what those traits are. We were able to look at that a little bit in this experiment, and we found that perhaps not surprisingly, that aerobic bacteria, bacteria that can live in the presence of oxygen, were more likely to be horizontally transmitted than obligate anaerobes, which would die if they're exposed to oxygen. We also found that several bacterial genera in mice that displayed evidence of horizontal transmission, those bacterial genera tended to be the same bacterial genera that are known to cause disease in humans.

18:16 SC: That would be something that would be damaging to the animal and maybe prevent it being passed down.

18:20 AM: It's actually bad for the microbe's fitness. If you were a bacterium and you evolved some kind of pathogenic effects to your host and you're vertically transmitted and you kill off your host, that's an evolutionary dead end for you.

18:34 SC: Right.

18:34 AM: And so, vertical transmission is thought to disfavor the evolution of pathogenicity whereas horizontal transmission kind of opens up possibilities to all parent lines because you no longer rely on a single host lineage. You can just jump to the next host lineage if you kill off your initial host. That prediction is exactly borne out by our data.

18:52 SC: And can that help us better understand or investigate a new bacteria or a new infection and say, "Oh well, it looks like it has some characteristics that we're already familiar with from these types of studies."

19:03 AM: So we looked in particular at food-borne infections and hospital-associated infections, and what our data suggests is that a lot of those infections arise because of opportunities for transmission. And it's simply just the propensity of microbes to be horizontally transmitted, predicts the rate at which they cause infection in humans. And so it's reasonable to start to think about ways that we can cut those transmission routes.

19:28 SC: Could this, a study like this, ever be done in people? I know we touched on this briefly before.

19:34 AM: I think the difficulty with people is these long generation times of humans. The generation is 20 years or so in humans. It's gonna take 200 years or more to conduct an analogous experiment in humans that we just took three years in mice.

19:49 SC: Yeah. And of course the control in the environment art.

19:51 AM: Right. Yeah. And that's a whole another issue that would be impossible. I think eventually, we will be able to start to understand the long-term inheritance, multi-generation inheritance of gut microbes as time progresses and techniques for characterizing the gut microbiota of humans continue to improve. We're going to eventually have long-term, multi-generational data sets. It just might take some time, 50 or 100 years.

20:17 SC: Okay, Andy. Thank you so much for talking with me.

20:20 AM: Oh, thank you.

20:21 SC: Andy Moeller is an assistant professor in the department of ecology and evolutionary biology at Cornell University. You can find a link to his research at sciencemag.org/podcasts. Stay tuned for Jen Golbeck's interview with David Lazer about his book, Politics with the People: Building a Directly Representative Democracy.

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20:43 Jen Golbeck: Hey everyone. Welcome to the book segment of the podcast. This month we're reading Politics with the People: Building a Directly Representative Democracy, by Michael Neblo, Kevin Esterling and David Lazer. I'm joined this month by David Lazer, and David, not to start on a dark note, but it feels an awful lot like everything is broken in the American system right now and that our voices don't matter much. Can you talk about the motivation for the book in that context?

21:09 David Lazer: The mechanisms that we have to connect people to government are, if they're not broken, they're not working well. Interest groups are a fact of life in democracy, and in some ways they're good, in some ways they're bad. But they're inadequate as being the whole way that the popular will manifests in policy.

21:33 JG: You talk about the idea of directly representative democracy. What is that and how did you set out to study the way it might work?

21:40 DL: So, with the idea of directly representative democracy is somehow to strengthen the connection between citizens and their representatives. Then what we came up with was a high-tech version of town halls, the idea that we could use the internet to bring diverse people together from a member's district to talk to their representative about key issues of the day. And our experiment is mostly about immigration. And the idea there is that this is a way both for citizens to learn about policy, but also for representatives to learn about what their constituents want.

22:16 JG: How did you test it?

22:17 DL: In a sense, we put democracy in a test tube. We created these experimental settings where we could test whether this idea would actually work. So what we did was we created these online groups mediated by standard group discussion software. We managed to get a number of members of Congress who courageously volunteered to be guinea pigs for these experiments. We had 12 US representatives and one US senator volunteer to meet with a randomly selected set of constituents to talk about key issues of the day, mainly around immigration, which is really one of the big issues that our country is confronting right now as well as a one town hall on policy issues around torture, and so on that were really at the fore around a decade ago.

23:08 JG: Is the technology critical to this idea? And did it work?

23:11 DL: The technology is just an enabling component, but then there were a set of rules about how we set these up. We wanted to make sure that we had a representative set of citizens. So we did a random set of people. Usually town halls attract people on the extremes on either end, and those people should have their voices too. But often times the people in the middle don't participate. They're drowned out. And the whole point here was to get a typical set of people rather than just people who are mobilized in the moment for town halls. We made sure that people who had participated were informed ahead of time. So they got some documents, short documents that got them at least up to the speed on the basics of the policy being discussed so that it was an informed discussion. And we made sure to diversify who got heard in these town halls so one person could not dominate.

24:08 JG: Okay. But didn't it still basically devolve into an internet comment section style discussion?

24:14 DL: That's a great question. These were really, unlike your comment sections of a lot of news reporting, these were very thoughtful, deliberative events. We actually had some rules around civility, around, let's say if someone posted something that was obscene or just obviously factors that we wouldn't post that. But in fact, we never had to invoke those rules. Out of all the town halls we did, not a single time out of many, many hundreds of comments. I think part of the lesson there is a lot of internet fora are very open, which has its benefits, but it also means there may be a lack of accountability. It may mean that the one bad apple can spoil the bunch. In this case, we just had say a randomly selected 30 citizens, and seems like out of 30 random citizens, there's almost never a troll.

25:15 JG: What did the members of Congress think of it?

25:17 DL: We spoke to or communicated with the members right after each of these events. They seem to really like it. They found it a valuable, a different kind of event, to elicit the opinions of their constituents. And we think if this was more routinely used by members of Congress that would give them a tool to evaluate the considered opinions of their constituents.

25:43 JG: So, what comes next?

25:45 DL: We're actually giving a copy of the book to every member of Congress. We hope to be able to present this also to newly elected members of Congress in December. And so our hope is to encourage members of Congress to integrate these kinds of communication measures into their regular routines. So I guess there are multiple steps here. One is that we hope members of Congress integrate this and directly invite citizens into group online discussions. But we also hope that third parties, and we would be among those third parties, but we could imagine, let's say the League of Women Voters or other kinds of civically-oriented groups to host events that have these ingredients, then connect members of Congress to a diverse set of constituents.

26:36 JG: Well, David Lazer, thanks for talking with us. The book is Politics with the People: Building a Directly Representative Democracy by Michael Neblo, Kevin Esterling, and David

Lazer. And it's available now. We'd love to hear from you too. You can share your thoughts with us on the Science Magazine's books blog, Books, Et Al. That's it for October, but we'll be back in November with another food book for your stack. Happy reading.

26:58 SC: 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 subscribe to the show anywhere you get your podcast, or you can listen on the Science website. That's sciencemag.org/podcasts. To place an ad on the Science Podcast, contact midroll.com. This show was produced by Sarah Crespi and Meagan Cantwell and edited by Podigy. Jeffrey Cook composed the music. On behalf of Science Magazine and its publisher, AAAS, thanks for joining us.