00:00:07:13 - 00:00:33:03

Clare

Hello and welcome. I'm Clare and you are listening to Microbe Talk, the podcast by the Microbiology Society. Yesterday we released our vision statement for Knocking Out AMR, the Society's new cross-disciplinary project. It outlined the key issues faced by the AMR community. The lack of understanding of the urgency of the crisis. A fragmented AMR landscape and a broken innovation pipeline.

00:00:33:05 - 00:01:00:16

Clare

The current drug development process is fraught with complexities and high costs. Pharmaceutical companies are hesitant to invest due to limited market access and reduced sales potential. Someone who is hoping to start to tackle these issues is Microbiology Society member Professor Paul Hoskinson. Paul is working on a £1 million project to use food byproducts to make anti-microbial production more cost effective and sustainable.

00:01:00:18 - 00:01:16:01

Clare

I caught up with Paul at our Annual Conference in Edinburgh to pick his brain on his latest venture and to find out how his project could reduce costs and speed up the timeline of discovering new antimicrobials.

00:01:16:03 - 00:01:26:04

Clare

So I'm delighted to be joined by Paul Hoskinson at the annual conference to share. It's great to do a podcast in person. As always, are you able to introduce yourself and your research?

00:01:26:06 - 00:01:54:14

Paul

Yes. So, I'm Paul Huskisson from the University of Strathclyde. I'm currently the Royal Academy of Engineering Research Chair in Engineering, Biology and Chair of Molecular Microbiology at Strathclyde. So when really evolutionary biologists and we work a lot on industrial strains and the evolution of industrial strains and how you go from a streptomycin which is a soil organism, lives pretty much anywhere in the world as lots of different strains.

00:01:54:14 - 00:02:05:15

Paul

They produce two thirds of all clinically used antibiotics and other drugs, and we try and understand how we domesticate them into industrial strains that make our drugs commercially viable.

00:02:05:21 - 00:02:13:01

Clare

Interesting. And I have now got you here at annual conference. I should ask, what is your involvement with the Microbiology Society?

00:02:13:03 - 00:02:27:20

Paul

So currently quite a few roles for the society. So I'm a council member. I am the co-chair of Building Communities Committee and I chaired the publications panel. So I oversee the journals and all of the activities that the journals do.

00:02:27:24 - 00:02:43:15

Clare

Okay, brilliant. And so I'm here to talk about your project. I came across your press release and went, Wow, this looks really interesting. So you're using food byproducts, the new antimicrobial drugs, and could you give me an outline or introduce this project for me?

00:02:43:17 - 00:03:10:00

Paul

Yes. So this is part of a recent government funded set of research proposals that were funded so via deceit, the Departments of Science, Innovation and Technology. And they asked BBC to basically administer this grant call and what they were interested in is is trying to take engineering biology. So the kind of more up to date version of what we used to call synthetic biology.

00:03:10:00 - 00:03:46:04

Paul

So trying to make microorganisms work for us using engineering principles so that kind of design, build, test, revise model of, of applying that kind of engineering philosophy to trying to engineer genetic circuits in organisms. And for many years it's been an academic process where people have just made materials change color and create logic gates for gene circuits and those

kinds of things, and really start to make engineering biology work for us as a society and that kind of socioeconomic output from microbiology.

00:03:46:06 - 00:04:14:11

Paul

So they wanted very applied projects that could be utilized by industry, but really trying to use those engineering biology principles. So as I said, we work on streptomycin, the antibiotic factories and what we wanted to try and do was see whether we could make not only the process easier to take the molecules to the clinic, but also try and make the the fermentations that are done on large scale.

00:04:14:11 - 00:04:40:04

Paul

So generally around a hundred thousand liter segmentations are used to make these antibiotics and try and make them more sustainable using waste. Now the problem you have with that is that they control the genes that express the antibiotics, and they're regulated a lot by the carbon sources that you feed them. So the carbon sources that we generally use in these fermentations are food grade carbon sources.

00:04:40:04 - 00:05:05:02

Paul

And if you're trying to feed a billion people on the planet, you don't want to use food grade feedstocks for fermentation. So we thought, okay, can we use waste products to do this? So we have a model system that we collaborate with GlaxoSmithKline on. That is the production lineage for a molecule called globulin acid. It's a beta lactamase inhibitor.

00:05:05:04 - 00:05:39:04

Paul

Okay. It's one of the W.H.O. priority drugs. So it makes GSK even off patent about £700 million a year. It's made by generic producers in the Far East and we're using that as a model to see whether we can start to use waste. So things like waste bread, potato, washings, which are all really laden with starch. Yeah. Problem with that is that when you feed them those kinds of carbon sources, they repress the genes for antibiotic production.

00:05:39:06 - 00:05:49:21

Paul

So what we need to do is engineer the strains using those engineering biology principles to modulate that carbon source utilization. I'm trying to overcome that repression of the biosynthetic genes.

00:05:49:23 - 00:06:02:05

Clare

Wow. Okay. So just to make sure I'm on there, this is the first time I've ever come across this like industrial production of antimicrobials. So what normally happens.

00:06:02:07 - 00:06:29:05

Paul

You tend to have several kind of scale. So what you do is you take your one mil of streptomycin, spores, stocks out of the freezer, and you tend to pour it into a standard flask, the size that you would generally use in a lab. Yeah, you'll grow that up and you'll get them to a certain level of biomass, and then you'll move them into a next stage fermentation that can be anything from 100 liters up to sort of a 10,000 liters to get more biomass.

00:06:29:05 - 00:06:50:14

Paul

And then you pump that into 100,000 liter vessel that's only about 50% full for antibiotics. What you do is you get them to the point where it triggers production, which is normally in response to starvation for various nutrients, and then you start to feed them a whole range of things. And it varies from strain to strain of a product product.

00:06:50:16 - 00:07:07:14

Paul

So it could be anything from oil to glycerol to glucose and salts. And then you feed that and you kind of maintain them in a production state until the vessel's full, and then you just kill the fermentation and harvest the the product from the fermentation.

00:07:07:20 - 00:07:14:06

Clare

Okay. Okay. And so the products that you're looking for is that so it's anti-microbial. And so is it like specific chemicals, that kind of thing?

00:07:14:08 - 00:07:44:19

Paul

Yeah. So the model system is kind of like acid, as I said, but all of our antibiotics are made in this way. Lots of anti-cancer drugs, immunosuppressive drugs, anti helminth thinks that are all made by streptomycin used in the clinic are generally made by these large scale fermentation processes. And one of the problems we have with developing these kind of molecules is that you discover something from the environment that makes an interesting product.

00:07:44:21 - 00:08:08:04

Paul

But in order to get to the point where you can make enough to safety testing and all of the assays that you need to prove efficacy is quite hard. The soil isolate doesn't often make enough of it, so you tend to do random mutagenesis to get them to make a little bit more of the product. So you can do that and then you start to scale up production.

00:08:08:06 - 00:08:36:03

Paul

And generally for an antibiotic, you might discover it one year by the time it's in production, which is can be ten, 15 years later at scale. But it's probably, you know, ten years, eight or ten years before that drug then starts to make a profit. So for the pharmaceutical industry. So that leaves you with a couple of years window to make all the profit you need to make before the patent expires and everyone else can have a go molecule.

00:08:36:05 - 00:08:56:18

Paul

So we think if we can engineer the strains using engineer biology and also make them more sustainable, we can reduce that discovery to profit time and make antimicrobials more attractive to industry again. So that's one of the big problems is because it takes so long to make a profit, industry tend to have moved away from from those drugs.

00:08:56:20 - 00:09:19:15

Paul

There's kind of lots of other things as well. So if you make an antibiotic drug, you have a lot of side effects, kind of anti-cancer drugs. If it makes you sick, you have falls out. But they're often still licensed because they extend people's lives in a life threatening disease with antibiotics. The regulatory processes around them are really quite strict in terms of side effects.

00:09:19:15 - 00:09:42:13

Paul

So trying to make them more attractive to industry and increase their profitability from these molecules is one way that we can get to that antimicrobial resistance crisis. And we think the methods with developing with Klaviyo on acid will be applicable to all of these kind of new drugs, but also to existing products that are made by fermentation as well.

00:09:42:15 - 00:09:51:11

Clare

Hmm. I suppose the sustainability kind of element of that is using waste products. I suppose that also then factors into the cost and as well.

00:09:51:11 - 00:10:13:06

Paul

Yeah, so it reduces the cost of the drug, so it makes it more easy to, to trust to low middle income countries which often don't have access to these drugs, and especially the newer drugs, which is probably where most of them are needed because the the cheaper drugs are easily available, are often used without the kind of level of stewardship that is really required.

00:10:13:08 - 00:10:24:24

Paul

So resistance emerges more often in the clinics. So then you need these these more at these new drugs and that and the more front line treatments. So hopefully it can come to democratize the whole process.

00:10:25:01 - 00:10:35:11

Clare

Well, it's really interesting and you touched on it slightly earlier, but what kind of food waste? The finding that there's like a special great that bread is great for for feeding these fermentation.

00:10:35:16 - 00:11:26:05

Paul

Well yeah there's lots of interesting sites for not only for antibiotics but also for lots of other microbial products, even for things like biofuels. So the attraction around biofuels has often been corn or sugarcane for antibiotics, the kind of groups of molecules that people have looked at, olive oil waste and even waste from from cooking oils as a potential feedstock for these kinds of fermentations, the precision that you need to switch on the biosynthetic clusters for the

antibiotics have often precluded people using kind of kind of doing the finger, in effect, inverted commas, but kind of dirty substrates because you need to have a predictive fermentation, you know, exactly when it's going to switch on.

00:11:26:05 - 00:11:29:13

Clare

So you can't just chuck anything in there because.

00:11:29:15 - 00:11:38:07

Paul

You get repression. And we see this in the lab some days, you know, streptomycin particularly primed for this. Some days they behave, some days they don't and they can be a bit annoying.

00:11:38:10 - 00:11:40:11

Clare

So don't work with animals, kids or bacteria.

00:11:40:13 - 00:12:07:12

Paul

No streptomycin. Most bacteria are right. But we we were looking at bread waste a lot of interest, bread waste for a lot of industrial processes. But we throw away millions of tons of bread waste each each year. And actually from the commercial bakers who make your kind of standard loaves, you combine the supermarkets, they throw lots of that way, but the consistency of the product is really good.

00:12:07:14 - 00:12:30:04

Paul

So you can get can a consistent feedstock. I mean, obviously we're not going to go for artisan sour dough, but that's one option. The other option is like let people buy things like pre-prepared potatoes. Often chips, that kind of stuff. The potatoes get peeled, the peelings go to waste and they're often dumped into water and the water's full of starch.

00:12:30:06 - 00:12:59:03

Paul

The problem with that is that you can't just releases effluent because you end up with massive eutrophication of of water bodies. So you have to treat that. But actually it's a really valuable feedstock and that kind of starch can be used for a whole range of different processes as well. Problem is that you need to make sure the organism encodes the enzymes to deep branch the starch, and then also break it down into its constituent parts.

00:12:59:05 - 00:13:13:24

Paul

And not all bacteria have that, but streptomycin is really good because they have this huge genome and lots of genes for the catabolism of of carbon sources. So we think we can actually manipulate that. The native genes tend to express as well.

00:13:14:01 - 00:13:24:04

Clare

As at the moment you're focusing on starch. Mieses But do you see that you'd need different waste food products with different bacteria? And is that kind of same finding exercise as well, These genes each Yeah.

00:13:24:08 - 00:13:59:20

Paul

I think it will be more broadly applicable. My first love is streptomycin, so we'll stick with the streptomycin side of things, but I think we can move out into other antibiotics. So things like tetracyclines and some of the kind of like peptides that are used as frontline treatments for drug resistant infections like vancomycin, they're all streptomycin products. So trying to apply the sustainability angle to some of these molecules and lots of pharma, not just our partners, but lots of pharma are trying to reduce their costs.

00:13:59:20 - 00:14:15:06

Paul

So they put in wind farms and they use solar panels to reduce the costs of, of the production of pharmaceuticals. And feedstock has always been the one that's been really difficult to tackle. Wow. So hopefully you can get to it.

00:14:15:06 - 00:14:17:10

Clare

You know, it's nice a win win, isn't it?

00:14:17:15 - 00:14:34:12

Paul

Yeah, I mean, I think we'll I think the project we've been funded will be able to understand some fundamental biology that we will be able to apply to a range of strains and hopefully we will be able to also understand kind of how we can apply this more and more precisely within the farm sector.

00:14:34:14 - 00:14:46:00

Clare

Well, it's really interesting. And so I suppose we will have to tackle that. The question is why? Why is it so important that we find new antimicrobials?

00:14:46:02 - 00:15:14:13

Paul

So obviously there is the kind of silent pandemic that everybody mentions, but kind of nobody has that level of urgency around it. I think with the kind of catastrophic pandemics like like COVID where it suddenly affected everybody simultaneously. But antimicrobial resistance name is is kind of it's there and we know it's there, but it's not always agents. It's not affecting everybody at the same time.

00:15:14:13 - 00:15:39:08

Paul

But the paper a couple of years ago in The Lancet, it's 1.27 million deaths a year related to antimicrobial resistance infections. We need to tackle that. We need new drugs because some of our old drugs are less effective. But we also need things like inhibitors for beta lactam disease. And the more we have of those, the easier it is to deploy.

00:15:39:09 - 00:15:57:01

Paul

And if you're using a whole range of drugs, then the resistance is not driven in one direction in in these illusory sense. So as drugs become less useful, you can cycle amounts of use and start to use a different one. And it doesn't mean you then can't cycle the old drug back in in a few years time. Yeah.

00:15:57:03 - 00:16:31:23

Paul

So we need new drugs and people are doing these kinds of experiments and looking to isolate strains that make molecules. And lots of people in the streptomycin field do this. It's a bit busy for me. I kind of found a slightly different niche where there's less competition in that kind of understanding production and evolution of production strains. But we also need to try and develop processes to because we're making a certain amount of the drug and that drugs useful.

00:16:32:00 - 00:16:49:19

Paul

We need to try and make that more efficient so we can make more of it, we can make it more cheaply and we can make it more available for people to actually use. I think the other thing with with with antimicrobials is we need better diagnostics as well so we can deploy the appropriate drug in at the right time, in the right place.

00:16:49:22 - 00:17:10:21

Clare

Yeah, Yeah. So it's interesting. So I hear a lot about, you know, why it's important to find new antimicrobials, but I suppose, like you said, there's a difficulty in making that kind of jump from in the lab into something that's more kind of scalable, I suppose, And so that's what your research is. It's, it's making that jump.

00:17:10:23 - 00:17:38:22

Paul

Yeah. So that scalability is an issue because if you can't scale from, if you have a, a newly found organism that makes one milligram of per liter, make it enough for the clinical trials to see whether the drug can be used on a large scale. To make enough of that for safety. Testing really is a challenge and I'm often far more willing to take that from academics.

00:17:38:22 - 00:17:55:09

Paul

And I think our idea is that we can design more rationally strains rather than the kind of empirical approach where you just randomly mutagenesis the strain and hope you get a high producer. At some point. We hope our technology will be more applicable across a broader range of strains.

00:17:55:11 - 00:18:04:01

Clare

And right now, are you operating as like a purely academic bit of research? Were you already kind of collaborating with industry at this level?

00:18:04:03 - 00:18:32:10

Paul

So we've collaborated with GSK for a long time and it's a really nice collaboration because they're interested in the kind of work that we do and they kind of give us quite a lot of freedom to work around their system and their strains. But we use it as a model. So yeah, and it's really nice because we could make our own evolved lineage and we've done that with a kind of model strain that's a lab strain.

00:18:32:10 - 00:18:49:21

Paul

And we've we've evolved a lineage by actually having something that was just driven to a production size kind of fermentation for those strains on simply does it make more coffee, lilac acid? Yeah, the previous strain, we already have that model.

00:18:50:00 - 00:18:50:21

Clare

From GSK and.

00:18:50:21 - 00:18:53:03

Paul

GSK been doing that for 35 years.

00:18:53:04 - 00:18:54:12

Clare

Right. Okay. So you're just picking up.

00:18:54:17 - 00:19:23:17

Paul

Some of their hard work. But they, they, their goal is to make more confident lining acid. And because it's only really in the last five or ten years we've had the high throughput genomics to be able to say, what are the changes in those strains that give rise to the strains ability to make a lot

of antibiotic. So we're applying genomics, we're applying transcriptomics to try and understand what's going on in the strains.

00:19:23:19 - 00:19:52:15

Paul

We're using large scale phenotypic microarrays to understand how the the what we call diet breath. So the ability of those strains to use a range of carbon sources when they live in the soil, they encounter all sorts of different things. But when you grow them for 35 years and in a fermenter and you evolved them to just grow on one type of media, yeah, they just start to get rid of genes that they don't need or they stop using those genes and they, they change that transcriptional landscape.

00:19:52:17 - 00:20:14:05

Paul

And actually we can see that they, they're less able to grow in a range of carbon sources now than when they started in that lineage. And that's kind of common. The Richard Lenski experiments on E coli has shown that as well. The adaptations bacteria in bacteria is that they don't use stuff that they don't see any more. There's no point in carrying those genes.

00:20:14:05 - 00:20:29:12

Paul

There's no point in using the energy to make the messenger RNA to make the protein if you never encounter that substrate. So understanding how that changes and that that also adds a complication to the kind of project we're trying to do with the food waste now.

00:20:29:16 - 00:20:29:24

Clare

Yeah.

00:20:30:05 - 00:20:54:10

Paul

Is that in a kind of, I guess what we as an evolution biologist, we would call it a fitness landscape. So you evolve an organism to grow at the peak of whatever that point on the landscape is for the media that you grow them on, but you change the substrate, which is what we're trying to do. You may have to take several steps back in order to be able to go to a different peak in that fitness landscape.

00:20:54:12 - 00:21:10:24

Paul

So to me, as an evolutionary microbiology, it's a really nice project to be able to try and understand adaptation and evolution of novelty in terms of how these organisms can grow in the environments and and what drives that kind of process.

00:21:11:01 - 00:21:43:15

Clare

Cool, cool. So it's like you have this industrial application, but there's also some really cool, like, like you said, fundamentals that you're hoping to find out as well. So I did it with you approached approaches or not, but so do you think that potentially in the future you'd be able to, as you said, kind of go back to then having to grow on a very specific substrate, so say, for example, a stance like a huge amount of waste from carrots or whatever, would you be able to then manipulate those genes to be able to say, okay, we've got laser carrots, Can you read that into the salmon?

00:21:43:17 - 00:21:44:03

Clare

I mean.

00:21:44:05 - 00:22:15:18

Paul

That's the planning and the feedstock. You can have an organism that has a flexible ability to use feedstocks that become available. And the some really funny historical stories about strip leases in industrial fermentation. So there's an organism, I probably should mention the company, but they had an organism that made a clinical useful antibiotic. And at the time there was a tax break on molasses from the Caribbean.

00:22:15:20 - 00:22:37:09

Paul

So they embarked on a production process to to get this strain to grow really well on molasses. So they used some what the time was kind of innovative ways of evolving the strain to grow molasses and then evolving the strain because the process, the ability of those strains to grow in fermenters also is a trait that you need to encourage.

00:22:37:11 - 00:22:56:09

Paul

So they had to Lineage is one that was good at growing implementers, one that was good to grow in on the carbon source. And then they made these things called protoplasm. So you basically strip the cell wall off, you mix the protoplasm together, they fuzed because they're only membranes, and then the genomes reassert and then you just select the ones that are good, both traits.

00:22:56:14 - 00:22:57:05

Clare

Wow.

00:22:57:07 - 00:23:05:21

Paul

So they spent about five years doing this work and they had a strain that was really going to grow in on molasses in their fermentation. And then they closed the tax break.

00:23:05:23 - 00:23:06:22

Clare

Oh, no.

00:23:07:02 - 00:23:32:08

Paul

All that work went in the bin. And now I would love to get my hands on those, right? Yes. But I don't think they exist, which is I think they've probably been able to cleave the way in, which is sad, but yet the process is kind of interesting. So this is going on. I think a lot of microbiologists, especially in the streptomycin community, they they grow there and they say we've got a strain and it makes loads of antibiotic that's in flask 100,000 liter ferment.

00:23:32:13 - 00:24:01:09

Paul

Fermentation is a very different ecological environment if you want to if you want to think of it in that way too, a shake flask so you have stress because of the the normally spread. So there's a thing called shear stress. So they get broken up and they get beaten all the time by these impalas spinning rounds. And you've got code that does lots of oxidative stress because they pump oxygen into the bottom to make sure it's aerated.

00:24:01:11 - 00:24:09:23

Paul

And that's very different to just sitting in an incubator in the lab where they're just being shaken very gently. And in a L in May, a flask.

00:24:10:00 - 00:24:23:14

Clare

Is interesting because, I mean, all of this brings you back to like the struggles of growing penicillin. It's just like it's kind of like an established problem that we're still kind of tackling today, which I think is really interesting.

00:24:23:17 - 00:25:01:00

Paul

And a lot of those issues with with growing Penicillium the same instructor sees that both filamentous organisms that are not unicellular rods that grow and then divide into two cells and become full cells, they grow as mycelium almost mycelium. And so they essentially it's a filaments of of bacterial cells that all join together and then they branch. Yeah, but in a fermenter or even in a shake flux, they get tangled up and they form aggregates and those aggregates are heterogeneous, so they might be nutrient repeats at the edges, but in the center that's starved of nutrients.

00:25:01:00 - 00:25:12:07

Paul

So you get this heterogeneity. And for production, what you want is a homogeneous fermenter where they're all making product at the same time. And actually that's not necessarily the case.

00:25:12:09 - 00:25:32:12

Clare

Wow. Wow. So you've opened a whole door of all this stuff. I didn't kind of consider in this in the first place. I well, it's so interesting. So you mentioned kind of I hopefully get into it to my CS towards an area where they're a bit less picky about what they grow under. So do you potentially see a future where you can put nondescript?

00:25:32:12 - 00:25:38:04

Clare

You don't have to be so selective about what you're kind of seeding them with. Is that is that possible to happen?

00:25:38:06 - 00:26:12:04

Paul

I'm probably not in my lifetime. I'm I mean, there's lots of lots of people using different approaches like cell free approaches to make antibiotics. They really of the lab scale. Yeah. So you basically take the transcription translation machinery out of the cell and you create a mini bioreactor that cell free and you add in just the genes for the biosynthesis of the antibiotic and all the precursors and but that requires you to understand what all the precursors is and, and what all the building blocks are needed.

00:26:12:06 - 00:26:20:07

Paul

So that might be the future. So think synthetic biology and engineering bio use open lots of lots of avenues in this area.

00:26:20:10 - 00:26:28:08

Clare

Yeah, definitely. And then I suppose more specifically, where do you foresee your research perhaps going in the next few years? What are your goals?

00:26:28:08 - 00:26:52:08

Paul

I think for me I'd really like to understand the adaptation and the parallels of that. I guess we call it adaptation. And then of course the evolution to make the product. We're really interested in trying to understand the processes and whether there are any parallels in those processes that we can then exploit to to try and enhance industrial strains a little bit better.

00:26:52:10 - 00:27:19:15

Paul

And I think those will also open the avenues that when we first started working with with streptomycin way back in the fifties when they discovered streptomycin, and Simon Waxman, the kind of godfather of that field, isolated the first streptomycin producer and found the first antibiotic that could be used against TB. I don't think we really realized the kind of bias and I think potential these organisms had.

00:27:19:17 - 00:27:41:10

Paul

So for many years we would isolate a strain and we knew it made antibiotic X or antibiotic Y, and then we sequenced the first genome. Then we realized they had the capability to make 20 or 30 different natural products. But many of these we have no idea what their function is. We have no idea what their biological role is in the environment.

00:27:41:12 - 00:28:08:04

Paul

So much biology to understand, and some of it could be really useful. And the more strains we sequenced, the more we discover new biosynthetic clusters that are just bizarre in terms of what we understand, in terms of how the regulated. There's also these these cryptic clusters. So sometimes we we know an organism can make a molecule that could potentially be interesting, but we can we can't find the biosynthetic clusters.

00:28:08:04 - 00:28:22:05

Paul

So trying to understand how they get activated and switch on and make more of a product. So the biosynthetic capability so actually the cycle of organisms, yeah, we don't need to isolate anymore, but we need to understand better the ones we've got.

00:28:22:07 - 00:28:44:04

Clare

Gosh. Okay. So the potential is just unraveling. Yeah. Wow, that is so exciting. And it's been great to have you here to pick your brain on that. I don't know what I thought about how antimicrobials are produced, but it wasn't. So thank you for explaining that to me is really interesting project and it's really exciting to hear it from you and it's great to meet you in person.

00:28:44:04 - 00:28:52:22

Clare

I normally do these over Zoom calls. It's quite nice to do a to a podcast in person. What are you most looking forward to the annual conference? It's still got a few minutes to go to.

00:28:52:22 - 00:29:16:15

Paul

I guess I think the talks this afternoon in the in the the microbial stress session that look really good but I might actually be jumping across to one of the forum sessions that the the microbial metabolism and physiology sessions itself. It's the early career scientists it's a really nice cutting-edge stuff that is kind of work in progress.

00:29:16:20 - 00:29:17:13

Clare

Excellent. Thank you so much for joining me. It's an absolute pleasure.

00:29:24:15 - 00:29:31:12

Paul

Thank you for wanting to hear about our work and kind of promote our project.

00:29:31:14 - 00:29:50:16

Clare

Thanks again to Paul for a brilliant Microbe Talk episode. If you want to follow him, you can find the details of his socials in the description. You can also follow the links in the description to find out more about our knocking out AMR project. If you liked this episode, please leave a like or comment wherever you're listening.