When Science Finds a Way

Season 3, Episode 4
Zooming in: particle physics and the future of medical imaging

Show notes

Episode Description:

Vaccine breakthroughs dominated the news during the Covid-19 pandemic. But they weren't the only scientific innovations changing how we understood the virus. Across Europe, a team of pathologists, technologists and imaging researchers saw a gap: we needed better technology to see what was really happening inside the lungs of individuals who died after contracting the virus. So they built one. Hierarchical Phase Contract Tomography (HiP-CT) is a new kind of imaging that lets us scan whole organs in 3D, in astonishing detail. Alisha is joined by four of the researchers behind this innovative approach to find out how it came to life during a global crisis, what it has revealed about Covid-19's impact on the body, and where it could take us next.

Mentioned in this episode:

Long COVID support - a charity set up *by* and *for* people with Long Covid and their carers in the UK.

European Synchrotron Radiation Facility - a research facility home to the most intense source of synchrotron-generated light, producing X-rays 100 billion times brighter than the X-rays used in hospitals.

Human organ atlas project - provides Hierarchical Phase-Contrast Tomography images of human anatomy from the micron to whole organ scale

Transcript

Music starts 00:00
Claire Walsh 00:06

With HiP CT, we could scan, theoretically, a whole human body, and you could create, like, a new reference atlas of the human body. This would be something really revolutionary for the field.

Alisha Wainwright 00:22

Welcome to *When Science Finds a Way*, a podcast about the science changing the world.

I'm Alisha Wainwright, and on this series I'm talking to the global experts who are making a difference, as well as the people who have inspired and contributed to their work.

Now, you may have heard of an X-ray, an MRI, or a CT scan. On this episode, we're going to talk about a new way of scanning that could change the way we understand the human body. It's called HiP CT. That's Hierarchical Phase Contrast Tomography. And it's an innovation that uses a particle accelerator the size of a football stadium to produce extremely detailed, three-dimensional scans of organs.

HiP CT was developed back in 2020, as the COVID-19 pandemic emerged. In those early days, researchers around the world were racing to understand COVID's effects on the human body – while working through lockdowns and social distancing measures.

Two of those researchers are joining us today to talk about HiP CT, how it came to be developed, and the exciting potential of this new technology.

Peter Lee 01:35

I think what really excites me is that, um, making a Google Earth of the body.

Alisha Wainwright 01:39

That’s Peter Lee, he is Professor of Materials Science at University College London.

Max Ackerman 01:44

It was a kind of Leonardo da Vinci moment in terms of the first images.

Alisha Wainwright 01:48

And that’s Max Ackerman – he is Full Professor of Pathology at RWTH University Clinics. Aachen, Germany.

In those early days of COVID, while many of us were staying at home, Max approached Peter for help analysing the lungs of COVID patients. That request turned into an international, cross-disciplinary project to develop the HiP CT technique at the European Synchrotron in Grenoble, France.

I spoke with Peter and Max to share their story and tell us about the insights and potential of this new kind of scanning.

Music stops 02:28

Alisha Wainwright 02:29

Peter, Max, welcome to the show.

Peter Lee 02:31

Thank you Alisha.

Max Ackermann 02:32

Thank you.

Alisha Wainwright 02:32

Let's go back to early 2020. Not that many of us want to do that, but Max, how did you first come to approach Peter about looking into the lungs of COVID patients?

Max Ackermann 02:43

Yeah. So we heard from these reports from Wuhan in China, and nobody really knows about this virus during early stage of the pandemic. And when COVID really hits Europe, February, March 2020, we started to conduct and carry out autopsies on, uh, patients that succumbed, uh, to COVID-19. And we realised that this virus is different that a respiratory disease, that a respiratory virus, so we found hallmarks of the virus by analyzing the tissue of those victims, and I contacted Peter and asked whether he would be interested to help us to characterise changes in these tissue we gathered from, from these autopsies.

Alisha Wainwright 03:25

And had you guys worked together before, or was this like a blind email?

Peter Lee 03:30

So I've, I've worked for over twenty years with Max's mentor, who unfortunately died ten years ago. So I knew well of Max and what he was doing, and he knew what I was doing, but we hadn't actually worked together. And we, we hadn't met in person

Max Ackermann 03:42

It’s true.

Alisha Wainwright 03:43

And I doubt you… With COVID and everything, did it take a while until you guys did meet in person.

Peter Lee 03:48

Three years…

Alisha Wainwright 03:49

Oh my gosh…

Peter Lee 03:49

…before we met in person. So we did a vast amount of work, probably hundreds of hours of video calls, and yet we'd never shaken each other's hands.

Alisha Wainwright 03:58

Wow. In the early stages of the pandemic, people reported a range of symptoms that went beyond what you'd expect from a lung-related illness. Did your research reveal any insights into this?

Max Ackermann 04:12

In earlier 2020, we started with our first paper on COVID-19. It was a seminal paper published in the New England Journal of Medicine, and it changed the perspective of the disease in that way that, you remember all the media reports on COVID-19, so it was described as a respiratory disease, but we found that the virus affects more than just the lung, so we see effects on different organs, on, on lung, heart, brain, and kidney, and we realised that also COVID-19 is, uh, really an injury of the endothelial cells, sort of the blood vessel lining cells by the virus itself. And imagine you have, if you line up all your blood vessels, you have a distance or length of more than eighty thousand kilometres. And if you destroy endothelial cells - not only in the lung - but also beyond, it's, it explains that you find these, these traumatic effects on lung function, but also on brain function and heart function. So you destroy vessels in the brain, which means that you destroy also the functions of those areas which are affecting memory loss. This effects of this virus was really long-term effect, long-lasting.

Alisha Wainwright 05:24

And of course, this was a new, relatively unknown virus, which was affecting people in many different ways. To help remind listeners about how wide these effects can be, we spoke to Margaret O'Hara. She's the founder trustee of an organisation called Long COVID Support, and a scientist who has both researched and experienced long COVID herself. She shared her experiences with us.

Music into 05:46

Margaret O'Hara 05:53

So for me, it's actually been different every time. I'll be sometimes so tired I can't even stay awake, and I just have to sleep. It's like I've been anaesthetised almost; it's really extreme. I mean, I don't know how else to describe it. It just feels like that. It's like a hangover that never stops. And I get strange twitching in my muscles. My muscles feel like jelly and I can't walk properly. But for other people, I mean, other people have all sorts of things that people talk about, brain fog, this cognitive dysfunction.

And then there's all sorts of other things, you know, there's, there's headaches, there's eye problems, teeth problems, skin problems, muscle problems, every single organ can be affected. It's your heart. It's the whole cardiovascular system. So we run, the Long Covid Support runs a very large support group with tens of thousands of people. And I think I've heard about every single part of the body being affected from some day at some point. And that's because the virus can get anywhere. Once the virus is in your bloodstream, then it can travel around and it can lodge in any organ it likes: gut, brain, lungs, liver, heart, kidneys, everywhere.

Alisha Wainwright 07:04

It's really striking to be reminded of how broad the effects of COVID can be. And remember, back in 2020, it was all so new. But Peter, your focus at this point was on the lungs. And I think your next step was to contact someone at the European Synchrotron Radiation Facility, the ESRF, in France. That was Paul Tafforeau, who is a paleontologist by training. So why was he the person to go to?

Peter Lee 07:35

So actually, I didn't know he was the person to go to. What I did know is that, that, what - my own background is in X-ray imaging - and so, I knew and had been using the European synchrotron. I'd been using it with Max's mentor, Moritz Konading, and, um, I knew to call them. I also knew that the European synchrotron, which is a particle accelerator, had just finished an upgrade to the world's first fourth-generation source. What that meant is it had special properties.

And so I called up Paul, and he had been designing a beamline to use these new properties that the fourth generation enabled. That lets you see very fine variations in density or X-ray absorption. Paul had done all of this because he studies the overall evolution of teeth in dinosaurs - so very different than looking at a lung.

I called Paul and instantly, like that, he came up with three or four things that would adapt all the beamlines that he was designing to use on soft tissue. And soft tissue is quite hard to actually go and resolve with X-rays. You think of that classic X-ray, the picture of the hand, right, of Röntgen's wifes hand. You can see the bones, you can see the ring, but you can't see the soft tissue. And yet, the soft tissue is exactly what Max needed to see. And it was what Paul had done, it was really going through, working on that, and improving the resolution as much as possible that we came up with this technique, HiP CT.

Alisha Wainwright 09:08

And now I'm going to ask a really big question. Peter, what is a synchrotron? And why was this so important to the development of the HiP CT scanning?

Peter Lee 09:19

So a synchrotron is a particle accelerator. Its the size of a football field. In fact it's a huge football field; a normal football field has a 400-meter or quarter-mile track around it. The synchrotron has an 800-meter or basically a half-mile long circumference. And what it does is it takes electrons - so those are the particles you use in a synchrotron - accelerates them almost up to the speed of light. When it accelerates, it gives off, and these electrons give off something called synchrotron light. And, they're also incredibly high brightness; they're 10 billion times brighter than the sun, so that means a huge flux, which means you can get really, really high resolution, and it's those properties of the synchrotron that enabled HiP CT.

Alisha Wainwright 10:03

And this is something that can really only be done on a deceased patient's organs because I can't imagine a living person withstanding light…

Peter Lee 10:12

So you're absolutely, absolutely right, Alisha. That's a critical point for, for everyone listening is that we get this phenomenal resolution. We can resolve at one micron or a 50th of a hair in something that's the size of us, where a normal CT will be a millimeter. But the flux is so high that no one living can go in, um, because they wouldn't be living for long.

Alisha Wainwright 10:34

Let's hear from Paul Taffereau who took us on a tour of the beamline control room at the ESRF, which is where he controls the particle accelerator. He explains how HiP CT scanning works and his part in its early development during the 2020 lockdowns.

Paul Tafforeau 10:52

The beam starts there, so we are at one hundred and seventy-four metres from the X-ray source, so the synchrotron is along a long tunnel on this side; the beam goes there through the slits, then it travels in air and then it reaches the sample that is on the tomograph. The tomograph is this small black box with the two organs on top…

I am Paul Tafforeau, the Beamline responsible of BM18, that is one of the beamlines of the European Synchrotron in Grenoble, France.

I started to work at home because we were in the lockdown, uh, on how to make this experiment. And it was a bit, uh, difficult time because we had to make a kind of a mental experiment of how we would do that. So during these few weeks, I made a lot of calculations and I reached the conclusion that, yes, it should work. It would be difficult, but it should work. And we started to think on how to prepare the sample. Because the main thing is, if you use too strong X- rays, you can destroy the sample. So a large part of the development of the technique was the development on how to prepare the organs, how to mount the organs and how to make sure that they will survive the very strong X-ray dose, we need to see the details without making new bubbles and without moving by more than two or three microns. So it's very, very challenging.

I had evidently no human lungs at home, as you can imagine, so I used pork lungs to do that. And, uh, after many, many tests, I finally managed to have some good mounting procedure. And when we were able to go back to the synchrotron, uh, I just applied everything I calculated before, and I was quite lucky because finally my calculations were correct, and when we had the very first picture, it was a ninety-five percent fit with the calculation I made. And when I saw the first result, after a lot of efforts, um, I was quite depressed because… And at this time I sent an email to all my colleagues and I said, “I'm sorry, it's a failure, it's not working, we cannot see anything in the data, the quality is really poor, so I'm sorry, we made all these efforts for nothing.” And I sent the data. And it turned out that it was the most beautiful picture of a lung they ever saw. It's just that for me, I was working on fossils, on things with a lot of contrast. And for me, the contrast we had was so low that it was bad quality. But for them, it was much better than everything they saw before. I'm not a physicist, uh, but in the present case, it was, uh, an advantage,

If you just follow the normal rules, uh, that you would read in any physics books for tomography, it will not work. But if you just do not understand anything and you do not want to understand that, you can try, and at some point from time to time it works. I mean, many cases it fails. In most of the cases the physicists are perfectly right. But in some cases, uh, you can see that finally, uh, thinking in another way can be useful.

Alisha Wainwright 13:52

Wow. It's incredible to hear Paul talk about how some of this early work was done literally at home. Um, Peter, what was it like trying to develop these techniques remotely and through lockdowns?

Peter Lee 14:06

It was incredibly exciting. Everyone I talked to was helpful, facilitated things, and because everyone wanted to fight COVID. And I was on the phone, or on video calls, with people in France and Germany, across the UK, going through and assembling the ethics, the health and safety to go and transport lungs from Max where he was performing autopsies on people who had died of COVID, through to the ESRF, getting the ethics to go through to the UK as well, and the UK synchrotron. Yeah, the, the synchrotron is like a James Bond set. It's just a huge super science toy that's, you know, bigger than a football field, and it's just amazing to deal with. That was, you know, adapting that needed Paul Taffereau's overall understanding of the imaging physics going through. Looking at the images and posing the medical questions, you need Max and his whole team, and then to actually quantify the images, deal with the images, you need us.

And so, when we started this, it was February 28th, literally within two weeks, we had over a dozen people helping: people helping with Max going through and doing the autopsies, people helping Paul go and adapt the machine, people helping me go through, analyse all of the results, and image them, and turn them into something that Max could see. We now have over fourty groups from twenty different countries around the world working together on this. And it's only through doing that that we're actually going to make an impact on disease.

Alisha Wainwright 15:33

Okay, well, Max, first, I want to know, what was it like when you first saw these images? I know Paul was very upset thinking that what he resulted in was going to be disappointing, but what did you think when you first saw them?

Max Ackermann 15:48

So I was totally fascinating by the, by the pictures. And I think for us was this a groundbreaking technology. So normally, so we working with glass lights and light microscopy. So you have a small field of view, high resolution; this is how we doing clinical routine diagnostic for our patients. But these pictures showed the same resolution, but on the third dimension, and thereby we could follow up mostly the vasculature in the lung, but also in the brain and the heart to see, yeah, how the tissue is changing and how, um, the ventilation of perfusion, perfusion was affected by the, by the virus itself.

Alisha Wainwright 16:29

So when you were able to see the scans of a COVID lung, what did those images help tell you about COVID's effect on the body?

Max Ackermann 16:38

Yeah, during this time, I think primarily on the intensive care units, they treated the disease as a respiratory disease, and antithrombotic, uh, drugs were so far not widely used uh, during this time. And by our New England Journal paper, but also the paper we published together with, with Peter, we could show that I think it's necessary to treat these patients very early with antithrombotic drugs. So, these are drugs that inhibit this excessive clotting, and thereby you prevent also that you have this, this tissue damage, which was driven by this clotting and, uh, endothelial injury, uh, driven by the virus itself.

Peter Lee 17:17

And I, I have to say that, um, I mean it was very scary because you could see a lung is made up of a whole bunch of lobes. And many of the lobes in these lungs that we scanned looked healthy, but some were just a mess - completely disrupted. And so it was really something which was a bit scary to see how a disease, a virus, could change completely the vasculature and the outlook of your lung in, you know, a week. So it was something which was both exciting and a little bit terrifying.

Alisha Wainwright 17:51

So HiP CT scanning showed this scary impact on the vasculature of the lungs, but this insight also showed us that treating patients for clotting could help. We asked Margaret - who we heard from earlier - what potential HiP CT could hold for patients, and where it sits with other research into COVID.

Music into 18:10

Margaret O'Hara 18:17

I found it really interesting to read about the HiP CT thing because, um, you know, they found these small clots in the lungs and that chimes with an awful lot of other research. So although there's a lot of discovery research going on, and although it's still in the early stages, what we're converging on from lots of different directions is vascular dysfunction. And part of that vascular dysfunction is clotting, inappropriate clotting. So it just keeps pushing your immune system to be active, which then causes a lot of inflammation.

And part of the issue with the microclots is the techniques to see them, because they're very, very small. So a lot of the techniques that we have in the NHS, they don't have high enough resolution to be able to see these and to see where they are. And if you could look into, into the body to see exactly where these things are, and what they're doing, then you might get clues about, you know, for some people - and it may be different for different people. It can be useful to say, “Okay, you're having gut problems. You're having kidney problems. You're having brain problems. Let's try and figure out what might be going on for you.”

And here is, you know, here is an example of where we've got a piece of tissue. We've looked at it with this high-resolution scanning and we can see that it's right into the microvasculature and it's causing this damage.

Now with something like this, it's really kind of blue skies discovery science. You've got this technique and the applications come later, you know, as, as that kind of filters out and you might not even have thought of the application.

Patient involvement is really key with this. So, obviously the researchers should be talking directly to patients and patient groups. I think that scientific international community is still coalescing. It's still very disparate in lots of different places at the moment, but hopefully it will coalesce into something fairly soon.

Music into 20:11

Alisha Wainwright 20:19

Max, we heard there from Margaret about the importance of scientists consulting with patients and patient groups. Can you speak on how working with them has helped your research into other areas, like breast and prostate cancer?

Max Ackermann 20:34

So what we heard before about COVID, it was a starting point. It was a good point to start with these, uh, to learning from those those tissue which was collected during autopsies, and it was really a challenging time because remember we had to shut down, we had the closed borders, so it was hard for us to bring the samples from from Germany down to to southern France.

And now it's different because we have set up a workflow and for all these kind of studies it's, it's our aim to involve those patient groups to inform them about the technology and really the advantages to, to participate in this study because a large number of participants on these, these studies, on different study sites in, in Germany, uh, it enlarges our volume of data. And a large volume of data means that we can have deep learning of those data, in the near future could guarantee a better diagnosis by preclinical, uh, algorithms that are driven by AI.

Alisha Wainwright 21:34

Okay, that’s exciting. And, Peter, can you talk us through some of the other applications of HiP CT?

Peter Lee 21:41

It's just been a phenomenal growth in potential applications. Every week I get an email from another group. So, um, last week we were listening to a whole group of medics and and scientists from South Africa who want to look at it, use the technique to look at tuberculosis and how tuberculosis develops, which still has a massive impact around the world through to going through. We went and scanned and analysed, um, the, uh, placenta, which has phenomenal vasculature, and it's really not well understood how the blood exchanges in between the fetus's blood and the mother's blood. And so we've scanned the placentas to go through and help get a better understanding of that blood transport.

And as, uh, Max said, you know, prostate and breast cancer. I've had an MRI scan of my prostate and looked at it; I'm not medical trained, but I know that it didn't show much. And that's what the analysis basically said. The HiP CT just shows vast amounts more. It's just completely night and day. And I think if we can do what he was saying, which is use AI to inform clinical techniques and get better clinical techniques, even if it's a small impact, it's really going to help.

Alisha Wainwright 22:52

Can I ask you both for your opinion here? What are other research areas in the life sciences that will greatly benefit from this new methodology? And what are some of the big questions that could be answered with HIP CT? I'll start with you, Max.

Max Ackermann 23:08

Yeah, I think it's a, it's a bridging technology between pathology and radiology, and both disciplines can learn from each other by adding this technique as a, as a bridge between the different questions both disciplines have.

And, and we can use all these data also for teaching. So, uh, I'm next to our clinical pathologists, also anatomists, and I'm using those data to show students how the lung, how the heart is really looking in 3D. It's different than what you learn from textbook. It's different what you see just on a regular CAT scans. We have gathered so many different data, and all these data are open source and, and using this data, this is, I think, for the new future, really a big challenge.

Peter Lee 23:50

I think what really excites me is that, um, making a Google Earth of the body - so having sort of a Google body where you can go through and zoom, and zoom into different organs. And what that will do is really let us treat the body as a system of interacting organs, where we can trace the lymphatic system, the vascular system, the nervous system between the different organs, between our brain and the different organs, and really see how they work together.

And also, I think it'd be pretty cool to fly through a body in 3D, in a virtual reality.

Alisha Wainwright 24:22

Totally, totally.

Peter Lee 24:24

And, and it'd be amazing because if if you had the disease - and we'd really love to do it in health, disease, and as we age - to see inside, you know, what happens as your teeth develop, what happens as you go through, and you go, and your heart starts to age. I think it'd be just amazing to be able to fly through at that level, at such a higher resolution than has ever been done before.

Alisha Wainwright 24:48

To get a sense of the broader possibilities of HiP CT imaging, we spoke to Dr. Claire Walsh, a bioimage analyst at UCL. She has worked on the team extracting quantitative data from these 3D organ scans. Claire explained the opportunities and challenges for the future of HiP CT.

Music into 25:03

Claire Walsh 25:09

With HiP CT, we could scan, theoretically, a whole human body and you could create, like, a new reference atlas of the human body based on real data, not on, you know, an anatomist's interpretation and drawings of it. This would be something really revolutionary for the field. There's kind of only two data sets really out there of whole complete human bodies that have ever been scanned, and a lot of our anatomy and our understanding of how human bodies differ from one another are based on these kind of data sets.

The other aspect that I think is really interesting is in the potential HiP CT has to impact clinical work in the hospitals. You can develop algorithms that will, will make our clinical scanning better. And that's really through areas, with the the brain, and comparing a HiP CT scan of a brain to an MRI scan, which you can do in a, in a living patient. In particular, with something like Parkinson's disease, a surgery that's often done for it is people insert electrodes into the brain, into specific parts of the brain, that give electrical signals that help with the symptoms of Parkinson's disease like tremor.

So there's a lot of, um, work at the moment to try and unpick what is the true wiring diagram of the human brain, the human connector they call it, so what parts are connected to other parts. The way that a surgeon plans where to put that electrode, if they do an MRI scan of the patient, um, and the MRI scan predicts probably where the wires in that particular patient are, but the way that the MRI scanner predicts it is not always super accurate, particularly for these deep brain regions.

And with HipCT, you don't have to guess where those wires are. You can see the wires. So we can trace these wires in the brain and we can say, Okay, the MRI scanner predicted that the wires on this particular brain were here. When we look at it in HiP CT, we see they're actually here. And like that, we can develop algorithms that are much better at detecting them in the MRI scanner. So eventually the surgeons use the algorithms that we've developed to interpret, okay, where should I be putting these electrodes in this brain?

The improvement of the algorithms for clinical approaches, it really relies on us being able to build up a really good database of HiP CT scans of organs where we also have clinical scans of those organs. And that, that's a challenging database to build up. That will take years to build up effectively, but it's, you know, something that we're working towards, and it's really exciting to be a part of.

Music into 27:41

Alisha Wainwright 27:50

Peter, can you tell us about the Human Organ Atlas project and how that aims to make the data from HiP CT imaging available around the world

Peter Lee 27:59

Absolutely. So we set up something called the Human Organ Atlas, and we did both multiple things.

One was we have a, um, a website, where anyone can go through and look at the data and zoom through it using online viewers, in what are huge data sets - can be terabytes for each data set.

You can also download the data, which I only advise if you have a big computer to go through - quite a big computer - and you can go through and probe it and analyse it. And so that's opened it up, and already in the year and a half since we've done that, there's been a half dozen other groups who've taken the data and actually published and done new insights into heart disease.

The other thing we did is we formed a hub at ESRF. And so there's nine different co-PIs - so we're all equal - from eight different institutes, five countries, six countries, I can't quite remember, and we're all going and helping each other analyse things. We're also bringing in other people, and we're training other people how to do it. We've got those nine core members, but then we have over three hundred scientists around the world who signed up and come to the online meetings to go through and use the results and propagate the technique.

Alisha Wainwright 29:19

So currently, HiP CT imaging can only be done at the ESRF, but there are other synchrotrons around the world. I think the one in the UK is the Diamond Light Source. Peter, what needs to be done to expand this HiP CT capability around the world?

Peter Lee 29:34

So, as you said, there's a number of synchrotrons. There's one in Chicago which is just finishing an upgrade. Diamond Light Source, as you mentioned, which is outside of Oxford in Harwell, is going to be upgraded in December 2027 to fourth generation.

But we're also working with a fellow called - a professor at UCL - called Sandra Olivo, who's trying to adapt laboratory source X-ray machines to do aspects of HiP CT.

And that's incredibly exciting. If we can do that, we can basically have HiP CT to go through and be part of the diagnostic route inside of hospitals. And that would really transform it. If we can do this with laboratory sources, you can scan the whole entire volume, and see, and really get a much more accurate diagnosis. So I think that's really an exciting aspect.

Alisha Wainwright 30:23

I'd like to finish off by taking a moment to highlight the cross-disciplinary collaboration in this story. It’s just incredible. We heard from Paul earlier, who is a paleontologist and Claire, who talks about being an image analyst working with pathologists to pull insights out of these images.

How important was that collaborative approach to the development of HiP CT?

Max Ackermann 30:46

I think it was a game changer because, as I mentioned, I think without these interdisciplinary approach, I think the whole project of HiP CT - and also the readout of COVID at that time - wasn't possible. Because, as I said, so I'm, I'm very open-minded to to any kind of innovation. So, if you have this, this synchrotron, which is really fascinating if you see it for first time in person.

And if you see then, these images - I think this is something which you need, especially if you, if you're seeing all these different tissues each day.

And for sure, um, the physicists behind this technique is immense and, and, and it's really very complex, and therefore we needed this interdisciplinary approach.

But at the end, we gathered really fascinating images. And as I said, I think it's a beauty of anatomy, as Peter just said, by these Google Earth of the HiP CT. And yeah, it's a kind, it was a kind of Leonardo da Vinci moment in terms of the first images.

Alisha Wainwright 31:50

Thank you so much for that. Peter, Max, thank you so much for your time.

Music starts 31:51

Max Ackermann 31:55

Thank you.

Peter Lee 31:56

Thanks very much, Alisha.

Alisha Wainwright 32:03

Thanks for listening to *When Science Finds a Way*. Thanks also to my guests Peter Lee and Max Ackermann, as well as our contributors Paul Tafforeau, Claire Walsh and Margaret O'Hara.

Wow – the technology behind HiP CT imaging is head-spinning. But, putting aside the photons and the beamlines, this was just an incredible human story. These scientists and researchers developed an innovative new technique while working through a pandemic. And this is also another example of something we hear about a lot in this series – the power of collaboration, across disciplines and borders.

When Science Finds a Way is brought to you by Wellcome – a charitable foundation that supports the global scientific community, working to build a healthier future for everyone.

Discovery Research is one of Wellcome’s priorities, along with Mental health, Climate and Health and Infectious disease.

If you visit their website - wellcome.org – that’s Wellcome with two L’s - you’ll find a whole host of information about discovery research, as well as full transcripts of all of our episodes.

It's also where you'll find the episodes about discovery research from the first two seasons of the podcast - or just scroll back through the series on your podcast app and you’ll find it there too.

If you've been enjoying *When Science Finds a Way*, be sure to rate and review us in your podcast app.

Next time, we’ll be meeting the researchers exploring how simple problem solving skills could be the key to improving young people’s mental health.

Vikram Patel 33:44

For me the question is not whether stresses arise, these are part and parcel of growing up. The question is really how are you able to effectively cope with those stresses in ways that do not lead you into a rabbit hole that ultimately leads you into a mental health problem.

Alisha Wainwright 34:02

When Science Finds a Way is a Chalk and Blade production for Wellcome.

Music stops 34:06