

Numberphile Podcast Transcript

Episode: Rockstar Epidemiologists - with Adam Kucharski

Episode Released February 2 2021

Adam Kucharski is among a number of epidemiologists who has suddenly been thrust into the limelight. We discuss his career and the current state of the coronavirus pandemic.

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[gentle piano music]

Brady Haran [BH]: Well for better or worse we're now living in a world where epidemiologists have become rockstars of the scientific world. Some of them are household names. Adam Kucharski's one of them and he's today's guest on the Numberphile podcast. Adam was born in the quintessentially English city of Bath, the his surname sounds less British to my ear. So before we got to the serious business of mathematics and disease, I asked Adam about the name Kucharski.

[music continues and fades out]

BH: So Kucharski, how do you say your surname?

Adam Kucharski [AK]: So that's, yeah that's how we say it phonetically. The Polish pronunciation's... slightly different. But it actually translates as cook, so... it's not that unusual as a surname in Poland but yeah in the UK. It's my grandfather originally...

BH: Yeah?

AK: He died back in the Seventies, so I unfortunately never got to hear his stories and... and sort of get that side of the culture.

BH: Obviously in the UK it's like a reasonably exotic surname but in Poland it's like pretty common?

AK: Yeah, yeah, [laughs] they probably have much easier time of spelling it than I sometimes do.

BH: As a youngster in Bath, you know, as a boy what were you like, were you destined for to get into the field you're in, were you really... were you mathematical? Were you nerdy?

AK: Umm. I think I always had an interest, yeah, in maths and puzzles and problem solving but I think alongside that I mean... always kind of had an interest in travel. Me and my parents worked abroad for a period of time before we kind of settled in the UK, and so I think I have had that interest in what was going on globally, I think I had that interest in science and obviously maths and then I think over the years sort of managed to converge on a field that enabled you to... kind of have that Venn diagram of all the different things. I played quite a lot of chess actually when I was younger and I think... as I got older it evolved into poker. My grandmother actually I think to my parent's sort of frustration taught me poker when I was quite little, which I enjoyed but they probably

didn't want their son gambling so much.

BH: [laughs]

AK: And then, yeah in terms of sports, I mean, I think a lot of the classic ones, so I think like hockey and cricket, yeah, a little bit of football, you know, a sort of standard mediocre [laughs] childhood footballer. In terms of just puzzles and problem solving, I think a lot of those classic books that you read as a kid, you know, things like Fermat's Last Theorem and those kinds of ones, just opened up that world of pure maths and proofs and... yeah I think for me there was always a bit of allure there which eventually lead me in that kind of track to do a maths degree.

BH: What did you do at cricket? What were you? Were you a batsman or a bowler or...?

AK: I was a bowler, a spin bowler actually.

BH: Spinner? Okay.

AK: Yeah... umm... I mean batsman was kind of, you know, going down the order, get a few runs and then get out cheaply.

BH: Yeah.

AK: I think was my... my style... yeah it was... but it was nice, yeah, the club I played for we had a really nice grounds just on the outskirts of Bath and it was... there was a river actually which is the county boundary which was just next to the pitch basically so you could literally hit the ball out of the county, which was quite nice. [chuckles]

BH: Nice. [laughs] Hit into the next county, I love it. Did you ever hit one into

the next county?

AK: Oh... goodness no. [laughs]

BH: [laughs] We you really into cricket stats? 'Cause when I was a boy like, even actually even now, one of the things I loved about cricket was the statistics and the numbers and you know... doing all that stuff.

AK: Yeah I mean I sort of... loved I think that element of it and kind of watching it and you know just getting to grips sort of thing. I was weirdly lousy at scoring though.

BH: Yeah?

AK: I think probably just got distracted chatting quite a lot and you know, so you know when you're scoring you got the kind of three tallies that always need to add up?

BH: Yeah.

AK: And it would... they would always be one out.

BH: Ooh.

AK: When I ended up scoring was when matches were coming down to the wire which is when you definitely don't wanna be one one... one one stray somewhere. So I think that was for me a lesson that I probably shouldn't go into something like accountancy but...

BH: Right.

AK: ...I think the mathematical side was still there though.

BH: If I went back in a time machine then and asked that young Adam, oh what'd you wanna be when you grow up? What kind of answers would I be getting?

AK: When I was very young, I think I wanted to be an astronaut.

BH: Oh yeah, yeah.

AK: And then... then I discovered that you need perfect eyesight, which I didn't have. [laughs] So I think then I sort of converted that, oh maybe I'll be a sort of... something along those lines, like being an astrophysicist or something to do with, you know, building rockets or something. And then I think just sort as I started doing more physics realized that there were other bits of kinds of maths and science I enjoyed more.

BH: Hmm.

AK: But that's probably yeah probably the default answer you would have got for a good few years.

BH: So as you got to the end of high school were you aiming at mathematics at that point? Like what were you applying to do at university and things like that?

AK: I was actually for a while debating between history and maths, oddly enough. 'Cause I think I quite enjoyed almost that sort of digging through the evidence aspect that you have in... in a certain part of history, you know, where you kind of have the arguments, sort of interpretation, you know, you kind of have the different sorts of evidence and you have to try and weigh things up, which quite appealed and so I think that's why although I ended up sorted going more down the pure maths route originally I kind of kept, you know, I sort of

write about science and I've always had a kind of interest in the history of a lot of these concepts and ideas, 'cause I think often the theory's very elegant but it's actually when it stumbles its way into reality you get a lot of that complexity and human element which I sort of find fascinating as well.

BH: So where did you go to university and what did you study?

AK: So for my undergrad I just did straight up maths at Warwick.

BH: Yeah?

AK: One thing that's nice actually about that course was you could take about a quarter of your degree from other departments. So I ended up doing some modules in economics, did some stuff in some bits of particle physics actually, did some courses basically the equivalent of an A level in French. [laughs] As a sort of... as a minor.

BH: Right?

AK: Which is kind of and then as I went on there was a lot more in kind of mathematical biology. So you could do courses in kind of genomics and newer sciences and these kinds of things so I think that opened that sort of side door, okay a lot of these mathematical ideas are actually, you know, really powerful in other fields as well.

BH: I have to ask why French?

AK: In part it was something that I'd always kind of been interested in and my uncle lives in Paris. I think I just quite liked the idea of having that ability to travel a bit more and get by in another language. Unfortunately though I actually, so when I later on, during my PhD actually tried to do a course to kind of get back to where I was but by mistake I didn't sort of realize the level of

assessment on it. So a lot of these exams were weekends and I couldn't make and so I basically emailed them and said, look you know, I was doing this as a side thing alongside PhD, it doesn't really matter if I do the exam or not. And then when I got my PhD transcript on it, it says, you know, Maths PhD awarded, Advanced French failed. [laughs] So I didn't actually realize I was taking a formal course that was gonna end up on my academic record.

BH: It's a blot on your copybook.

AK: [laughs] Well it's also now there as sort of evidence that I'm not very good at French.

BH: [laughs]

AK: [laughs]

BH: What's your memories of that new world of mathematics that opens when you go to university?

AK: I really enjoyed it. I mean it is, it is a bit of a whirlwind especially going into a lot of these areas like kind of real analysis where you're talking about convergence and different concepts of infinite series and really, you know digging down into the... the nuts and bolts of how proof works essentially. So it's a kind of moving away from some of the things where it's sort of laid out a little bit more clearly and actually getting you to think more conceptually about actually what does it mean to demonstrate something. And I think that's quite polarizing, I think some people quite... they find that quite difficult because, you know, it's quite a way from the more applied stuff they might have done at A level but I loved it... I thought even just the very kind of abstract theorems you can end up getting to grips with, I think that's a really nice intellectual challenge.

BH: It sounds as though, though from what you said before that the other

stuff, like the applied stuff, was still important to you, like you were enjoying those modules and you still like, you know... would you have described yourself as a guy who loved math just for the purity of it or it was important to you that it was being applied somehow?

AK: I think overall I sort of wanted to go in a direction where it was being more applied. There's this sort of intellectual challenge of just, you know, doing a puzzle or, you know, you play a game that has that kind of element for example, which is interesting for its own sake but I think I wouldn't have wanted that to have been a hundred percent of my life. Yeah, I think I enjoyed having that as a component and it was great going through that experience but I think as I went on I realized I wanted to spend more and more time actually trying to tackle real life problems that had real life implications.

BH: So what did you do for your PhD, then?

AK: Officially it was in applied maths but it was quite... heavily in epidemiology by that stage too. It was essentially looking at the dynamics of seasonal flu.

BH: Right?

AK: So in particular looking at how immunity builds over flu season, how, you know, these viruses evolve, work out how to elude immunity and then you get, get kind of subsequent outbreaks. I mean there's quite a kind of cool mathematical challenge that just in terms of combinations that, you know, if you have two or three viruses circulating, that's not that many combinations to work out what people could have potentially been exposed to. 'Cause you know if you have N viruses, it's basically two to the power of N combinations of past infections. But then if you get something like flu where, you know, over someone's lifetime, twenty or thirty distinct strains could have circulated, then, you know, you can't... you're not in a world where you can just write down all

possibilities anymore and actually... from a kind of tracking point of view it becomes far harder. So a lot of my PhD was actually just working out clever ways of simplifying that kind of, you know, two the power of N problem, down into something where you could actually understand, you know how this lifetime of accumulated immunity might influence the dynamics of outbreaks.

BH: Adam was there a person or a reason or something that happened that made you go down the epidemiology route?

AK: There were a couple of courses actually I did at Warwick that I think, you know, really jumped out for me. I did a course by... a researcher called Matt Keeling who's still there and it was a really nice course 'cause it had just some really interesting modeling and mathematical ideas in there but also he spent quite a lot of time running through case studies of where something that's apparently obvious in terms of, you know, understanding an outbreak, didn't really make sense and then a mathematical insight could help a bit of understanding of what was going on. So one example for instance is Malaria, you know, if you look at overall dynamics, people on average get infected at very young age. If you treat it essentially as one disease and you try and calculate the reproduction number, because people get infected so young that suggests there's a huge amount of background infection and you actually get reproduction number estimates of like, you know, a hundred or just huge huge numbers.

BH: Hmm.

AK: But increasing kind of work, about twenty years ago now, maybe slightly more, realized that actually there's several variants of Malaria circulating so if you actually separate it down into the separate circulating parasites then on average each specific one, people are getting infected with at a slightly older age but when you look at it in aggregate you get this impression of something that's kind of really high exposure rate. So, you know, these individual circulating parasites have a much lower reproduction number, so the kind of transmission of

each specific strain is lower, but it is that... that sort of feature of when you aggregate things, you know, I mean it's the equivalent of doing a calculation of waiting for a bus or waiting for a bus or car or anything else to go by. You know obviously that latter event is gonna be far more common, and so for me those kind of insights linking to kind of real world data persuaded me that that was something that'd be really interesting to pursue.

BH: You must've had a few other things on the table though as you were doing courses in, you know, economics and particle physics and things like that. Was there a reason that it was the epidemiology that grabbed you? Was it an inspiring lecturer? Was it just innately the more interesting thing to your personality type or...?

AK: I think it was. I mean it was a couple of things. I think like a lot of people in that era, I ended up doing a internship in finance, I think pretty much everyone I know despite their very diverse careers they've ended up in did something in the city in one form or another. Yeah I did an internship on a trading floor in 2008.

BH: Right.

AK: I mean it was fascinating to get a sense of that world and obviously maths is used a huge amount in terms of trying to price up these different financial investments. But partly for me I didn't really see it as a long term career that would kind of keep my interest. And I think also, you know, 2008 was the, you know, the Lehman Brothers going under and sort of a huge disruption in the industry and so I think that was making a lot of people rethink, as well, is this actually the industry you want to be in. I think already by that point the kind of seed had been sparked and it was actually that summer talking to a lot of people, a lot of the kind of quants who specialize in modeling about their memories and what they really enjoy, and a lot of them quite clearly, PhD and that part of their lives, was something that they really got a lot out of, and it made me think, if I've

got this opportunity to do more study, you know, worse comes to worse in a few years I'll decided to change my mind and go back into industry or something else.

BH: Hmm.

AK: I really got the impression from a lot of people who'd been in that that they'd got a lot out of it and for me it seemed... like that was an experience I wanted.

BH: But as an alternative to working on a trading floor, I mean I can see why working on a trading floor for your life might not appeal, but... I also would think at that time why would studying, you know, diseases and nasty infections and things like that be something you want to do for a career?

AK: Yeah, I mean I think that also, you know, there'd a bit of background presence in my life. I mean my grandfather had polio and sort of basically spent his life unable to walk and so I think the impact of disease and you know having a career where you're not just getting to tackle some really interesting scientific questions but also you potentially could have an impact on how countries can respond to outbreaks. I think for me that was a really nice balance. And it also had that element that had been then from years past of the kind of, you know, understanding the history, understanding the kind of social and behavioral context, which enabled me not just to be kind of looking at theoretical models but actually linking it very much into, you know, society and behavior which for many of these pathogens is... is what causes outbreaks. You know, so it's a kind of social feature of transmission as much as... you know biological one.

BH: We're gonna come to COVID and coronavirus in a moment and obviously that's made epidemiologists like you absolute rockstars. [laughs] But before that, before this had happened, what did you think your career was going to look like? Did you see yourself going into academia and just, you know,

putting out papers and studying flare ups for life or did you see yourself going into like the medical industry? What did you think was gonna happen?

AK: So I think before COVID, a lot of my work was going in the direction where there were really a couple of parallel threads of research. One was providing outbreak support to different country, different collaborators, you know, so we'd worked previously on the Ebola outbreak in West Africa, we'd worked on things like Zika as they emerge, so using models with various governments and various kinds of NGOs and other organizations to try and give them... give them insights essentially so they could do their job better. I mean, you know, we did some work for example over the Christmas of... I think it was 2017... of the diphtheria outbreaks in the refugee camps in Bangladesh with MSF. So again it's kind of just giving people additional context that they might not other have to respond. But alongside that I was also building up with various collaborators a lot more actual studies of different aspects of epidemics and transmission. So we had various projects around the world looking at things like immune responses and how populations have shifting infections and flare ups, so not just doing the theory but actually going out and collecting data that we could then use to refine our predictions about how these epidemics are working.

[gentle piano music]

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[gentle violin music]

BH: We've come to COVID and coronavirus. There seem to be two reactions people have these days. One is, gosh who would have thought the world would change like this, we never saw it coming, you know? And there's another school of thought that, well it was always going to happen eventually, you know, it was inevitable. What were you like? You look at the world now, the way things are and we're all locked down and we have these tremendous problems that we're trying to grapple with. Are you of the thought, well, I'm not surprised, it had to happen eventually or are you like, gosh who would've thought it could get this bad?

AK: [laughs] Unfortunately... a pandemic's been on our radar, I mean, for a long time. I mean, that's in the field of infectious disease, you know, a big pandemic is what motivates, you know, a lot of this work. People develop forecasting techniques and big flu models and these kind of things because of that threat. I mean obviously pandemic flu was an obvious one because of what we've seen in emerging kind of bird flu strains and other things in Asia. But given the emergence of SARS and then MERS obviously that caused outbreaks in a few places in the Middle East and South Korea in 2015, a novel coronavirus was also very much on that list, that if you had something was, you know, a bit more flu like than SARS, spread a bit more easily, then you could quickly get a major problem. But I think one thing that has been a surprise is just the global diversity that we've seen in responses to the current outbreak. I mean if you look back even... 1918, the big flu pandemic is probably the last event that was this globally destructive in terms of pandemic, but a lot of the responses you have parallels. There were islands in the Pacific that basically shut their borders and introduced quarantine for a couple of years, you know, American Samoa was the most notable one. And that response has been mimicked in one form or another in other places. We saw in 1918 that the US, a lot of cities, basically had

lockdowns. They shutdown shops, bars, schools, but weren't able to keep that in place and you know they had it in place for a couple of months, lifted it, then got another outbreak and tried to strike that balance. And there's also widespread debates about do face masks work, there were debates about what to prioritize and even... through the media coverage there was a lot of debate about, you know, when... is this even an unusual year, you know, are deaths actually that high compared to what a normal year would be.

BH: Hmm.

AK: So, for me, a lot of the kind of... I think diversity in response has been very interesting globally of what countries have chosen to go in what direction, but unfortunately there's also a lot of echoes of history that I think even a hundred years later a lot of these debates and these kind of approaches... could almost have been lifted out of what we saw in 1918.

BH: I feel like sometimes people in your position have to be kind of diplomatic because of their job, but you're right there have been so many reactions and so many different policies by different countries and also so many... different places have been hit to different extents. Do you think authorities have done well, or not well in there treatment of it? Everyone's different but are there winners and losers here?

AK: I mean I think... essentially everyone's lost out to varying amounts. I mean I think every country's had to make sacrifices but I do think what's made it probably a difference globally is in the constraints that the different countries or have thought they've had.

BH: Right.

AK: So you know for example, it's very easy in a model just to... you know turn on lockdown and leave it on indefinitely. But of course in reality, you know,

no country is gonna do that. But I think what has been a feature of different responses is some countries have said, you know, this is an impossible constraint, we can't possibly close down for this long or put this kind of measure in place. Then have ended up doing it anyway. And so that indicates that that wasn't really a constraint, that was a kind of perceived constraint which you've then gone back on. And then you've had other countries, you know, so for example case like Korea and Taiwan, which used very intensive tracking and surveillance and you know, getting people to adhere to quarantine which hasn't been used in the West in the same way but they had a lot more success with that, and then similarly some countries have imposed very strict border restrictions, made the choice to do that, and have kept it in place. Other countries have taken much longer to get to that point. A lot of our work obviously focuses on the epidemiology but I mean ultimately these are decisions that need to be made by politicians and they need to decide what their constraints are and you know, I do think there's gonna be a lot in hindsight and in reevaluating whether did some countries essentially put constraints on themselves that weren't really constraints. It was just something they thought they couldn't do at the time but later realized that they could. But likewise, you know, I think we're gonna also have to think about what the longterm is, you know, we're not out of this pandemic yet. And we have a vaccine which seems to do really well at protecting against disease but it's not clear still exactly the effect it will have on transmission in different places. So I think even just that question of how our different government gonna use vaccine as a tool alongside what they're already doing, I think there's a lot more debate to come probably about what do we prioritize, when do countries start relaxing thing, you know, what's the endgame from where we are now.

BH: Prior to vaccines, of all the things that were done around the world by different governments and authorities, is there one of the sort of... the weapons that you think was most effective and was the best thing that was done? And was there also a greatest blunder that you think some countries did they shouldn't have done and cost them?

AK: There's been a lot of debate around the use of data, and particularly around, you know, privacy which is quite rightly is a... you know a big consideration.

BH: Hmm?

AK: But a lot of the countries if you look that had very successful early responses and continuing responses have made a lot better use of tracking and understanding where the infection is. So if you look at Korea, Singapore, Taiwan, that tradeoff in terms of you know, allowing a little bit more data in terms of working out where the infection, working out who needs to be in quarantine, has enabled a lot more freedom in society.

BH: Right?

AK: And I think that was seen as a bit of a kind of redline by a lot of Western countries. I mean I suppose in the converse, yeah, so I think that has been a feature which has been very powerful in a lot of countries because it has enabled them to control outbreaks more locally, but I do feel that in some particularly, yeah in Western countries, drawing that very hard redline has probably hampered responses. I mean, you know, for me there's lots of different aspects certainly that I think need to be reflected on quite strongly, not just this pandemic but the next one. But I think a big frustration for epidemiologists have been not only having measures that might not work but having measures where you can't even estimate if they're working, you know, so things like the contact tracing apps, you know, that are very good at protecting privacy but it's actually very hard to work out if they're having any effect because the data you'd need to evaluate it isn't actually collected and made available. I think that has been a bit of frustration, we're seeing even with somethings more recently where we're, you know, we're still debating the exact effectiveness of different control measures. And I think because countries often put in measures together and lift

measures multiple things together, it's actually very hard as a, sort of, experimental design to work out what's having a bigger and a smaller effect. And so I think that choice has created a bit of challenge for scientists because essentially we haven't got that... that sort of neat, staged introduction and lifting of measures that would give you essentially the statistical signal to work out what's having a larger and a smaller effect and as a result a lot of countries have ended up relying on these more severe lockdown type measures because they can't be confident about what the individual components are doing.

BH: And what about a blunder? Something that happened either here or abroad that you thought, oh gosh I wish they hadn't done that?

AK: An enormous one for several countries early was just not only not realizing they had a problem but denying they had a problem. I mean the US stands out but I mean other countries, that essentially weren't really testing or looking for virus and assuming that meant they didn't have any.

BH: Yeah.

AK: And unfortunately I think we're seeing that reflected in some other countries now with the emergence of new variants. And so I've sort of said quite a few times over recent weeks that countries have to treat this like a new pandemic and for me one of the big barriers to the response in Europe in spring was people were so focused on Asia they missed the huge epidemics that were developing within Europe. You know, if you look at the UK, if you look at genomic data, our imported cases early on didn't come from Asia, they come from Italy, they came from Spain, they came from France, at times when those countries hadn't reported large outbreaks. And I think even now there's still a lot of discussion in Europe about preventing these variants coming in from the UK, which I think is sensible, yeah to have that discussion if you've got a new threat outside your borders but we're also seeing evidence, a lot of these countries have a lot of this variant domestically already, so you know, if you think of the kind of

network structure, if you're focusing so much on one node in the network and forgetting about all of the kind of indirect routes through which that contagion could spread, that's exactly the problem that a lot of countries had early in the outbreak, that they were essentially just looking at one link in the network and forgetting about all the indirect routes that it could take. And I think we're seeing a bit of that again where countries are sort of focusing on where the infections been reported rather than as we know well now that the huge number of other countries that could have these outbreaks undetected.

[gentle chimes]

BH: Obviously, you know, you do a lot of mathematical modeling and you're dealing with data and that. How important is it for someone like you to understand the wet biological side of things? How this virus actually works? How it's actually transmitted? Do you get it from touching stuff? Do you get it from breathing? Like how much do you have to have medical knowledge and how much can you ride above that and just depend on the mathematics and the numbers and sort of be obviously to the reality of what's going on in the cells and in our noses and in our lungs?

AK: We talk a lot with people on the lab side and people on the medical side because obviously whatever we're doing we wanna make sure is informed by what's actually going but in terms of the nuts and bolts of say how things grow within a host, how things transmit, it depends a bit on the question that you're interested in. So you know, if you're interested in the average amount of transmission currently going, so things like R estimates, you know, on average how much is each person spreading it to another, you can get that kind of number at a relatively top level scale, so you don't really need to know the exact progression of infection and sort of viral load within each host to be able to calculate that overall population picture. But it does become more important for example if at the individual level, you know, you're talking about say, I dunno, quarantine strategy against new variants, you know, if new variants change the

profile of viral shedding for people then the timing, you know, quarantining someone for ten days against the old variant might not have the same implications against the new variant depending on that individual level of biology. So for us it's often a matter of sort of tailoring it to the question we're interested in and then making sure we're collaborating with relevant experts on that, so over recent months we've done a lot for example on higher frequency testing and these rapid tests and this sort of thing, so we've worked with people who're doing these kind of studies in reality or, you know, people who are doing regular sampling of healthcare workers and really understanding the data on, you know, how much are people shedding, you know, what's the kind of different levels of virus at different points during the infection and then obviously when we develop a model of different testing approaches we're putting in that kind of hard biology to make sure we're getting something as realistic as we can.

BH: When the pandemic first started there wasn't much emphasis on masks. All that mattered was what you touched and how often you washed your hands and then it felt like after a month or two suddenly it was all about the masks and it became much more that this is an airborne problem, when that wasn't the case at the start. And I'm just wondering how that affects someone like you? Like, you know, if you're doing looking at data on should we be wearing masks, what's the effectiveness, how far should we be standing apart, and things like that. These things seem to really matter how it spreads.

AK: I think it makes a huge difference particularly for the advice you give people. I mean, so in our models we often sort of aggregate at a scale where, you know, you don't have individual people sneezing individual particles in your model. Yeah, you might for example have a household...

BH: Hmm.

AK: ...and then you'll use information on household risk to put together that

kind of model structure. So for example, if you have someone infectious within a household, from early UK data, they had about a thirty percent chance for infecting one of their contacts. So we don't know even now, you know, how much of that is virus that was on a surface, virus that was kind of transient droplets, virus that was airborne, but we know that overall risk within that kind of unit of a population. So we can put together a model that gives you a sense of what estimates...

BH: Yeah.

AK: ...for what the household risk is and what the risk is in different places. But of course what we don't have is, you know, that ability to say with confidence, you know, if you have ten people in this room for this length of time, this is the exact transmission risk that we're gonna have. And then, you know, then it's much more about the kind of the biology side and, I guess, sort of fluid dynamics and these sort of things come into it. I think your point where there was almost certainly too much focus just on the kind of surfaces and the short-range droplets early on, and probably not enough acknowledgement... I think there still isn't, that, you know, you still see people being very concerned about distance but not worried about say being two meters away from someone in a small stuffy room, which, of course from an airborne point of view, is an enormous problem.

BH: Hmm.

AK: And I suppose it also just goes to the challenge in this kind of situation of operating on limited evidence. I mean there's been huge debates about masks and, yeah, has someone done a clinic trial of it, what's the exact effectiveness, and I think for me one of the really useful early studies was in Hong Kong where they had basically everyone wearing masks out and about in public and they still got a sort of second wave that was not quite as high in terms of transmission as other areas but still quite substantial, so for me that gave a kind of a bound on

potentially what masks could be doing. So masks alone clearly aren't enough to stop the outbreak that was going on in Hong Kong, but their reproduction number was a bit lower than we might've expected otherwise. So for me that kind of gave a... okay, ballpark this might be doing twenty or thirty percent. I think in that debate around masks and how to quantify these values, I think has been really interesting 'cause it does show just the almost the different philosophical outlooks people have on evidence and how they interpret it but ultimately we're in a pandemic, we have to make decisions and if we have some evidence from a multiple number of patchy sources we have to do something with it.

BH: We're seeing a bunch of vaccinations rolling out now, and it feels like at least among some people there's this sort of sigh of relief in feeling that we're getting out of the woods now. It's alright, everything's gonna be okay. Is that a feeling you share?

AK: I mean I think... these are fantastic tools to have now available. And I think anyone you'd asked a year ago about the availability of vaccines to have these trials come through with multiple vaccines showing really good efficacy by the end of the year, I think it's just a remarkable achievement for science and even the mRNA vaccine, it gets scientists excited to see the science as well. It's kind of the actor's actor of vaccines. It's really not just a hugely valuable tool for this outbreak but potentially for future ones as well. But I think, you know, we do as with all control measures need to be aware that there might be some limitations. It does look like there's really high effectiveness against reducing disease and particularly severe disease which is really important 'cause that's where a lot of the impact of COVID is coming but it's not clear yet exactly the effect it has on transmission. 'Cause you can imagine, you know, if it protects people from getting severely ill but they still get a mild infection and can transmit then the concept of herd immunity doesn't work in the same way, because you're not having someone vaccinated who can't transmit, you're just sort of preventing them getting disease. So I think Israel is gonna be one of the

earliest signals we're guessing, because they're vaccinating at such high rates, I think probably in... sort of towards the end of January, February, it's gonna be quite clear what the effect of some of these vaccines is having. 'Cause ultimately if you have a situation where they don't reduce transmission a huge amount but they reduce symptoms essentially you've got to vaccinate everyone in your risk groups and then you gotta think about what other measures you want to have. More optimistically if vaccines can prevent transmission then they might do a huge amount to controlling outbreaks and we don't have to rely on these hugely disruptive measures. And I think the other point that perhaps doesn't get enough coverage is, it's just a global perspective as well, you know, in the UK there's a huge roll out, I mean, relative to other countries, in vaccines but there's some parts of the world where they're not gonna get widespread availability of vaccine for perhaps two, three years. And that... in terms of global travel is gonna create a huge problem because even if countries have vaccinated their populations if you have the virus circulating and potentially evolving globally, this problem isn't completely over yet.

BH: I know this isn't your area of expertise but I'm amazed we can't know that about the vaccines. Like, can't you just give someone the vaccine... expose them to the virus and then ask the to sneeze into a agar dish and find out whether or not they're still sneezing out the virus?

AK: There's a couple of challenges with doing that. I mean I think the first is just the kind of study design of how you do vaccine trials. So there were discussion actually over the summer of the so-called human challenge studies, where you're essentially vaccinating someone and then challenging them with virus and then seeing if they become infected.

BH: Hmm.

AK: I think the issue with that though is the people you want the vaccine to work for most are the ones who are most at risk of severe disease and they're the

ones that those kind of challenge studies become risky if not unethical for. Because you know it's one thing challenging a twenty year old, it's one thing challenging a...

BH: Yes.

AK: A seventy year old who's at much higher risk if the vaccine doesn't work. I think another issue is, is what we call correlates of protection.

BH: Hmm.

AK: So there's a lot of studies coming out now where there, yeah they're taking blood samples from people, say you've had the old variant and they're testing it to see if those the antibody response or the kind of neutralizing immunity in that blood sample can tackle the new variant. So that's a really useful measure of whether the immune response is having an effect or not against the new virus... but it's not clear how that correlates into actual protection, you know, is that person gonna get ill, is that person gonna transmit to others and so that's a sort of key bit of information I think we don't yet have. Because as you say, ideally we'd just be able to do lab studies, work out, you know, is this person responding to a new virus, is this person responding as well to these different vaccines and translate that into what it means for the outbreak but I think until you have that you've got this kind of relative comparison but you can't actually put numbers on what that means for infection or disease.

BH: Adam if I made you Prime Minister tomorrow, or President of the United States tomorrow, what's the first thing you'd do to help protect us all from the coronavirus?

AK: [laughs] I mean I'd... [sighs] I think... I'd... I'm sort of happy at the moment being an epidemiologist. I think politicians have a very different job in terms of everything that they're trying to... organize and weigh up.

BH: Hmm.

AK: But I think... for me... there's... yeah, vaccine is on the horizon. You know, if we didn't have a vaccine currently, the debates and trade-offs would be very different potentially but we've got a point where in two or three months we could have pretty much all the highest risk people protected as well as many others and so I think for me getting that roll-out working quickly and efficiently has to be a priority, especially in countries that have got themselves in position where they can have lot of the vaccines available but then I think also thinking very seriously about the disease burden you're gonna have in the meantime. You know, I think there's quite a lot of speculation at the moment of how quickly countries should ease-off. I think there's this idea that you know, once you vaccinated the over seventies, the over eighties, it's all fine, but of course there's already enormous pressure on our hospitals and there's also a lot of people in younger age groups that are showing up in ICU and so I think we have to really... at the moment not just in the UK but... everywhere particularly ones with new variants, get to this finish line [chuckles] without incurring a huge disease burden along the way. You know, I think for me if there's vaccines that can create an endpoint, you know, to sort have huge numbers of hospitalizations and deaths in that relative small window before those people are protected, I think to me that just seems completely crazy.

BH: Is there a finish line? Some people will say this will be with us forever. Other people say, by the end of the year it'll be like a distant memory. Is there a finish line for COVID-19, coronavirus?

AK: I don't think there'll be a hard finish line. I mean think there's a point where with vaccines we can be confident that the more at risk people have a much much lower risk than they would've, say a year ago, but I do think we have this problem that the vaccine... the virus is gonna continue to circulate globally and particularly until we understand how well vaccines are gonna work

against new variants and whether we can develop new vaccines, I think it is gonna be an ongoing challenge. I mean data came out this week from couple of studies in... in... South Africa showing that the new variant there is not neutralized as well by existing immune responses, so basically if you've been infected with the old virus you can't rid of the new one as easily and signals that perhaps that's similar for vaccination.

BH: Hmm.

AK: So, a lot of people who kind of work on evolving viruses are, I think, converging on the idea that this may end up similar to something like flu where we have to update our vaccines every now and again and actually seasonal coronaviruses, although they're much milder in terms of their impact we do see this evolutionary change over decades with these kind of infections. So I don't think it's gonna be the case that it's gonna be eradicated like smallpox or something was but I think we will gradually get to the point where the risk is much lower. We can be far more confident that this isn't gonna cause huge disease burden, that, you know, that we're protecting people against the majority of variants. But I think at the moment it isn't totally clear if that pessimistic scenario where, you know, you've got that constant circulation and evolution, essentially playing cat and mouse with us, isn't going to happen. So I think optimistically we'll be at a point where we can get on top of the current situation and deal with new variants, with new vaccines, but I think countries still have to be planning for that possibility that... this isn't gonna fully go away, and again what do they want that trade-off to look like in terms of the effort required to keep it out, certainly in the short-term versus, you know, moving to a sort of model where they're updating vaccines and they're out of being a bit more responsive to new variants but not having this level of stringency of measures in place.

BH: Is there anything you do on a day to day basis to protect yourself that is above and beyond the rules in the UK which are already pretty strict? I'm just

wondering [laughs] if there's anything you're doing that I should copy, like, do you keep three meters away? Do you not go out between certain times? Do you wear three masks or do you just do what everyone else is doing? I'm just curious what an epidemiologist does when he or she goes out to the shops. [chuckles]

AK: First of all I'm quite fortunate to be in a position where I can work at home. I think one of the big issues is just that variation in risk that there's obviously a lot of people who have to go into work or have to go for one reason or another.

BH: Hmm.

AK: I think given that, you know, even throughout this, even in some I think were relaxed, I've sort of tried to not go up to the limit of what I can do by the rules because, you know, I think, I'm in a fortunate position where I'm at less risk so can make more effort to try and not contribute to the epidemic.

BH: Hmm.

AK: I mean I think in particular, yeah, the risk if you're outside and if you're more spaced is much lower, so I think throughout this I've sort of thought more in that context where I've worked quite hard to avoid, you know, being in enclosed spaces with lots of other people but equally been more relaxed about being in spaces that are in the outdoors or well ventilated. So I think it's that kind of... it's almost like a multi-dimensional risk calibration, that it's not sort of measuring out two meters and thinking it's safe and unsafe, but actually just being far more relaxed if you're in a big outdoor space but being, you know, disproportionally... well proportionally more cautious if you're in a kind of busy closed environment.

[gentle piano music]

BH: You've got this book out at the moment, a new book, which I haven't got my hands on yet. It's called the Rules of Contagion and I was reading your little two or three sentence summary of it on your website and you don't mention the word COVID or coronavirus in that short summary. Is your... is this new book got a lot of that in it or is it a lot broader?

AK: So the original book actually came out in the UK last February, so it didn't have any coronavirus by that point 'cause I'd finished it about the time actually the first cases were emerging.

BH: Right?

AK: But we... the new paperback is sort of coming out at the end of... January... that has been updated with quite a lot on COVID, because there's already quite a few parts of the book that talked about concepts which are now incredibly relevant. So talking about genetic sequencing, talking about things like phone tracking or you know flight networks or second waves even. I think there was a picture of second wave on the second page of the book.

BH: Yeah.

AK: But it made sense obviously given what's happened over the past year to update, so there's quite a lot of changes to the chapters to... to reflect what's going on. I mean I didn't want it to be a book about COVID because I think there are these parallels between outbreaks where, if you learn the concepts you can apply them to a whole range of issues and that's really the idea of the book but there a lot of features of the current outbreak where I think there are those parallels and that's what the book tries to draw out.

BH: I'll have a link to the book in the notes for this podcast but what's it like working in your field now? You've gone from being quite... quite a niche field to like... the most important thing in the world. Like it must be like... when

someone becomes, you know, incredibly famous overnight sort of thing, the way you're world has changed. Your head must be spinning?

AK: It's been very strange and I think a lot of... I mean a lot of epidemiologists and a lot of scientists have become very prominent. And I think in a way it's been... sort of just strange to see that dynamic, you know that...

BH: Hmm.

AK: A year or two ago on Twitter you'd just bounce ideas around with other scientists and now you do it and you inadvertently cause a headline. And I think that's been a bit of a sort of strange transition and to some extent it's changed the way that you have to interact with these things.

BH: Hmm.

AK: But I think it has been good to see sort of prominence given to those ideas and I mean I think for me one of things that I just want to have done over the last year and continue to do, is just make sure that people are really thinking through the logic of what they're talking about and what they're suggesting, because there, you know, there are difficult decisions ahead and I think people and governments have to go into those with open eyes, you know, whether it's saying if you choose to relax things this is what you might see in terms of your outbreak or if you're talking about some kind of testing strategy just realizing that, you know, these are the characteristics you test, this is what it's gonna look like, and I think it has been good over the last year to see almost that mathematical literacy in terms of outbreak increase massively. I think everyone now is comfortable with the idea of reproduction numbers, most people have a better grasp of how data lags work, you know, cases come down then hospitalizations come down then deaths come down. I mean I think in small way I hope that I've contributed that over the last year and you know, by taking to journalist and talking to people in the media, have at least helped people make sense of what's going on.

Obviously it doesn't fully solve the problem 'cause there's no super easy solution to this but I think as long as everyone's kind of on the same page so at least we're getting the basics right and then we can move on to what's really important

BH: If I get to interview you again in twelve months, do you think it will be in person?

AK: I hope so. I mean I hope with the... with the vaccine rolling out we can at least get to the sort of levels we were seeing last summer. You know, I think there inevitably will be some restrictions that remain in one form or another, either whether we're talking about this kind of global evolutionary risk of new variants because if we're vaccinating our population we need to work quite to protect that immunity. You know we don't want to be in a situation where we vaccinated most people and then we get something that comes in and it evades the vaccine, but I hope once we get to that point even if we can't have, you know, massive thousand person parties yet we can at least get gatherings 'cause I think it's been a really tough year for everyone and... you know, I think things will get better. [music fades in] But you know it will take some time.

[music fades up and continues]

BH: Our thanks to Adam Kucharski for joining us today. Links to his work and the book we mentioned are in the show notes. You'll also find a link to G-Research, today's episode sponsor. [music continues] This podcast is made possible by the Mathematical Sciences Research Institute, MSRI, in Berkeley, California. I'm Brady Haran, and you've been listening to the Numberphile podcast. I hope you'll join us again soon.

[music fades up and out]