Numberphile Podcast Transcript
Episode: Gondor Calls For Aid - with Kit Yates
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Mathematical biologist Kit Yates discussing the coronavirus pandemic.

Kit Yates website

Kit on Twitter

The Royal Society's call to arms for mathematicians

NHS advice on Coronavirus and COVID-19

Ben Sparks on Numberphile - The Coronavirus Curve

3blue1brown on the exponential growth of epidemics

Simulating an epidemic with 3blue1brown

Tom Crawford on the SIR Model

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[gentle piano music]

Brady Haran [BH]: With much of the world currently locked down by the Coronavirus pandemic, mathematical modeling has become a household talking point. [music continues] To discuss this I'm speaking with Kit Yates, he's a mathematical biologist at the University of Bath. In this ever changing climate it's probably also worth noting we recorded this interview on the 30th of March, 2020.

[music fades up and out]

Kit Yates [KY]: By mathematical biologist I think people find that a bit of a strange one to deal with because I think people think math is quite pure and abstract and biology is pretty messy and real world and never the twain shall meet but really what I do day to day is take biological systems that I think are interesting so maybe anything from a swarm of locusts to the way that eggs get their patterning or the way that embryos develop and try to write down a system of equations or computer code which describe that to try to make predictions about those systems.

BH: Kit you say that people don't often see the link between biological systems and mathematics I feel like that's changed pretty rapidly in the last few weeks. [laughter]

KY: Right everyone is talking about exponential growth, about epidemiological models, about modeling and basic reproduction numbers, Boris Johnson was talking about the fast upward tick of the curve and yeah, even Conor McGregor, I saw the other days was talking about implementing half measures to halt exponential growth of the disease in Ireland so yeah everyone is talking about mathematical biology at the moment so it's a good time to be a mathematical biologist.

BH: Is there a degree of that… I know I'm sure if you had a magic wand you'd make this all go away and what a terrible thing this is for the world but are mathematicians thinking, At Last! People get it.

KY: Right, I think that's true I think people there's a good meme going round where it's just a guy standing at chalkboard drawing an exponential curve and students saying well, when are we ever gonna need this, right? and it's sort of the case it sort of feels like a little bit of vindication… although yeah of course ideally you would wish it away if you could do but I think mathematicians are trying to make the most of this opportunity and try and show people why maths really can be important. It can be a matter of life and death sometimes.

BH: Do you feel like this has showed up sort of a problem with mathematical literacy or do you think people have kind of risen to the occasion and they're getting it, like how have you felt about how well the public are understanding some of these things before we do start talking about them ourselves.

KY: Yeah I think people are doing an okay job actually I think the fact that people are actually talking about it and caring about you know how good these models are and asking these questions is a really good sign. I think its a little bit difficult to explain all the really complex models that are out there at the moment. But I think actually the basic mathematical models that underly epidemiological spread are actually not too difficult to understand in fairly straightforward terms and I think its our job as maths communicators to try and make those things as understandable as possible and I think there's a lot of good people out there working really hard to do that.

BH: Where do we start? What is exponential growth?

KY: Right so technically the mathematical definition is when something grows in proportion to its current size then that's exponential growth or equally it could be something decaying in proportion to its current size, that's also exponential growth so for exponential decay you can imagine taking a bag of M&Ms if you want, throw the M&Ms on your kitchen table on day one and eat all the ones that land on the M side upwards right so roughly half the M&Ms will disappear. Put them back in the bag save them for tomorrow, give them another shake up the next day, eat all the ones that have an M on them, and everyday you'll be eating roughly half of the M&Ms so the number of M&Ms is going to be decreasing in proportion the number of M&Ms you have left and therefore you'll be getting an exponential decay of M&Ms over time. So something is decreasing in proportion which means that the time it takes for halve or decrease by certain proportion will be the same no matter how much of that quantity you have. So that's exponential decay at least.

BH: So Coronavirus, let's deal with that for a second. That's exponential growth.

KY: At the moment, yeah, like so the way the simplest mathematical epidemiological models work is you break the population down into three different compartments. They'r called susceptible, so people who haven't had the disease. Infecteds are people who have the disease and can infect it to other people and then we have this removed category it's sort of a euphemistic term for people who have recovered but also people that have died.

BH: Right this is the Sir model we hear talked about.

KY: Right

BH: S I R

KY: We call it S I R but Sir, whatever you want to call it really.

BH: Yeah

KY: We at the very early stages you have a whole bunch of people who are susceptible to the disease and very few people who are infected and so each individual can go and infect a certain number of people who are susceptible, we call this the basic reproduction number of the disease. and if that number of people that they infect over the course of their infection period is greater than one then they will on average infect that many people who will then go infect that many people again so for COVID at the moment estimates of the basic reproduction number are between one and a half and four so it's quite a big window. The two and a half is generally sort of acceptable number, so the first people goes and infects two and half of the people, they're gonna infect two and half more and two and a half more and the exponential growth then occurs. You start to see the numbers growing exponentially.

BH: The way people seem to be getting this across is… or the nature of it seems to be it starts off as a slow trickle and then suddenly becomes like this huge waterfall.

KY: This is the thing about exponential growth, right, everyone… I think people confuse it with being big or fast all the time but actually if you think about the amount of money in your bank account or certainly my bank account, like it's growing exponentially you're getting interest proportional to how much money you've got. But the rate of interest is really low so you don't really see that exponential growth properly, it's just really really slow. If you left it long enough then great you'd get loads of money but who can leave their money in the bank account long enough. And that's sort of what you see the very start of the epidemic. You hardly notice these cases trickling in and then all of a sudden it seems to just absolutely take off when the number starts to really grow and that's the sort of danger of exponential growth is that if you don't recognize it early on then you can think, Oh this isn't a big problem, and actually you really need to be acting on it and taking steps which is what we're doing at the moment.

BH: It's these grains of rice on a chess board is the famous story, isn't it?

KY: Right, exactly, so uh… yeah the Emperor of China rewards this guy for saving his life and he comes along and says, you can have anything you want, and the guy this farmer says I'll just have you know one grain of rice for the first square on the chess board and two for the next and four for the next and if you could just complete that pattern that would be great and the King… the Emperor is like why yeah whatever that doesn't sound like very much you could have anything you wanted [laughter] and he chose this stupid amount of rice and then of course it's doubling every time you put rice on the next square it's more than rice than you've already put on the whole of the rest of the chess board so it turns out something like you'll have rice down to the knees or something across the whole surface of the Earth in the end. So yeah it's surprising, like counter intuitive if you like.

BH: Do you think the public has gotten that now or do you think we got it too late or like just as an observer. I know you're not like a politician or like an expert but it seems like you know, are people understanding this?

KY: Yeah I think the message is getting across to people I people are starting to realize as they are still seeing the numbers rise and rise, day on day we're still in this exponential growth phase so deaths are doubling every two to three days, cases are doubling every three to four days, so a little bit slower. But I think people are starting to get alarmed by the fact yeah we're having two hundred deaths a day and maybe more. And that's worrying them and they're seeing the numbers go up but not just go up in a linear fashion but actually sort of doubling every two or three days and I think people are starting to get the point that actually because exponential growth can be so fast anything that we can do early on can make a tremendous difference later on like we can really change the numbers later on if we can just make small changes even now. And there was this nice infographic that went around that showed that if one person infected two and a half people in five days then after thirty days they would have infected four hundred and six people, and actually if you can reduce that by fifty percent it changes from four hundred and six to fifteen people. And if you can reduce it even further by seventy-five percent which is there some of evidence that that's sort of what we're doing with our social distancing, you can reduce that number of total infected people to about two and a half including the first person who was infected. So you can really wipe out this epidemic if you can reduce this spread enough.

BH: So, it's about getting that two point five number to something closer to your bank interest.

KY: [laughter] right exactly if you can reduce I mean even your bank interest would be naught point you know half a percent per year right, even if we can reduce COVID spread to less than a hundred percent during the course of their infectious period then then you'll start to get this exponential decay, if you can get just go below replicating itself so just below zero percent then you'll start to see this exponential decline. But yeah, if we can bring it down to the rate of bank interest then we'll start to see very very slower exponential growth.

BH: What kind of jobs are mathematicians doing at the moment? Like I can see the job of doctors and I can see the job of researchers trying to come up with vaccines. These graphs and models you're talking about have been known long before COVID came along and obviously they're being applied now. But are there day to day things mathematicians can be doing, like new work they can be doing to help in this battle?

KY: Yeah absolutely. 'Cause every disease is different, right? And these simple models that I've sort of described, this S I R model, they can be made infinitely more complex. Right, so S I R is fine for some very simple diseases but actually there's extensions we can make to those S I R models to include things like a carrier class, so people who have the disease but aren't necessarily symptoms. So they're not necessarily you wouldn't class them as infected because you don't know their infected yet, but they've had this asymptomatic period, which is what is happening with COVID. And so they can be spreading it without you even knowing that they're infected and then can be a real problem and it has been a real problem with COVID, because we can't just isolate people as soon as they show symptoms we have to be isolating everyone in case they've got symptoms.

So that’s just one really simple extension you can make but adding in things like noise, so stochasticity or randomness in the way that people bump into each other. Taking account of the networks with which interact with each other can make a huge difference as well. You get these people are social hubs and therefore will spread the disease to lots of people compare to people who are stuck at home and don’t go out so much. So you can make these arbitrarily complex and there’s actually been a call by the Royal Society for Rapid Assistance in Modeling Pandemics where all mathematicians, especially applied mathematicians who have a familiarity with modeling can sign up and help out in this cause, so yeah there’s to loads to be done at them moment and we’re keeping really busy.

BH: Kit, how does someone build in something like these you know hubs super spreader type as opposed to people who are locked away. Like I see that they exist but how would you put them into a model? These sort of unmeasurables or like I see could guess at what they are but then how do you?

KY: So they’re not necessarily unmeasurables, we actually know a lot about our social structure in part from using social networking data but also there’s been a number of studies done and you could actually classify the way that people interact using a network. So people are nodes in that network and they’re connections to other people are edges. So you can classify what’s called the degree distribution of that network which tells you how many people are there who have a hundred contacts, how many people with ninety-nine, ninety-eight and so and down to how many people there with no contacts. And that distribution can tell you a great deal about the way that people interact so you can incorporate that network modeling into these S I R models you start the disease off in a particular node with a particularly connectivity. How many people do they actually interact with and you see how it spreads around the network. So, they may seem almost intangible but actually if we have good enough data and this is what it all comes down to really. If we have good enough data then we can actually capture these behaviors. But data at the moment on this emerging pandemic is really difficult to come by.

BH: You talked about randomness and I know that's a real expertise of yours, can you give me an idea how randomness would feed into for example the coronavirus COVID situation. What are some of the random factors and how can mathematicians use them?

KY: Well so it's sort of interesting that actually in the what we call the deterministic models. So the models that don't have noise in them. If your basic reproduction number is above one then your epidemic definitely takes off. Even if its only a tiny amount above one. And if its below one then it definitely dies off. But actually in models which build in noise or stochasticity you can tolerate being slightly above that threshold of R zero because in reality not everyone has the same number of contacts with everyone. There's noise and not every contact with someone else passes the disease on. So actually in reality you can actually have a non-zero probability of the disease dying out without having a big epidemic, even if you have this basic reproduction number being above zero in the deterministic model. Whereas yeah in the deterministic model it says it definitely takes off and then it dies out, but when you build in noise you can actually realize we can tolerate a little bit of spread above this basic reproduction number of one.

BH: One of the things I've found interesting has been the use of graphs where the Y axis has been logarithmic I think, so they take away that dramatic curve and everything becomes straight lines. And that's been used a lot comparing the spread in different countries. But there's something about those graphs that I somehow find deceptive. Like I know you're a mathematician and you can straight away process but what do you think of the use of those graphs?

KY: I don't think they're super helpful, actually. I was actually reading the comments below the line which you should obviously never do on the BBC article the other day which showed these log or what are called semi-log plots, so you have log axis so that you can really see how things are changing, the problem with having with a linear axis you don't really see what was happening early, it just looks like zero cases then all of a sudden it blows. Whereas the log you get this nice sort of straight line and it tells you what the exponent is. How quickly things are growing. Which is useful if you're studying the disease. But actually the comments below the line people like saying well there's clearly some mistake in this graph because the space between ten and a hundred is the same as the space between a hundred and a thousand, and that's the point of a log plot, but it's not actually that helpful unless you know something logarithms. So I, for me, I would steer away from those a little bit. Yeah.

BH: I mean I'm no expert but I think I agree with you on that. There's something almost like it makes the growth so steady and calm when it's a straight line, you think, Oh well you know if we do something now it will be all right, but like it doesn't show how it's running away from you.

KY: No and you compare the different number of countries cases and when you see that in a log plot you're like, oh, America's not very far ahead of us, I thought they were doing really badly, and actually like they are doing pretty, they've got a lot of more cases than us on an exponential, you know on sort of a linear scale it does look pretty bad. But on the log plot it doesn't really look like they're that far ahead of us but yeah it can be deceptive so I would steer away from using the log plots a bit I think.

BH: As a mathematician but also as a human who you know who doesn't want Coronavirus to be terrible, what are some of the numbers and graphs and things that you're looking at most closely and that you're really interesting in and that you're really hoping change or get dealt with?

KY: Right, so since we've had lockdown for about a week in the UK at the moment, and actually it's sort of too soon to tell what impact that's having, but even today we've been seeing the number of hospitalizations has gone down slightly, the daily hospitalizations that is. And similarly the number of cases that have been reported is going down. You can't read too much into that because actually not everyone is being tested. People are being urged to stay at home if they have mild symptoms, which is really sensible. And so… but we're testing everyone, so you can't read too much into it. But it's hinting that some of the early measure that we took like, telling people to work from home and banning gatherings are having an impact. It's a bit too early the impact of the lockdown yet and certainly like deaths is the figure that you really want to look at because deaths you know report all the deaths you don't miss any of those cases, right? But actually we won't really see the impact of the lockdown on deaths for probably a couple of weeks because there is this long period that you're ill for before you get seriously ill and then potentially go on and die. So but those are the really important figures is looking at case numbers and looking at numbers of deaths and once we start to control and bring those down then we know that the impact of the effects of the lockdown and the measures that we've been taking to control the disease.

BH: I mean what numbers can we give mathematicians other than positive tests and deaths?

KY: Yeah that's the tricky thing at the moment. There's a group led by a guy called John Edwards who are looking at other measures, so encouraging people to log how they are interacting with each other. So trying to figure out what the basic reproduction number would be if they were just talking to each other.

BH: Of course another piece of data is people going into intensive care I guess and things of that and ventilation and stuff but…

KY: yeah, so hospitalization data is something that's useful cause you don't go to hospital unless you're really serious and we can measure those numbers but it's not part of the data that's officially released by Public Health England everyday but it can give us an indication as it already is doing because the numbers are coming down a little bit per day that the effect the measures that we've been taking are generally having some effect at least.

BH: So as mathematicians produce different models and things like that that they can then give to policy makers, what are the levers the policy makers have? Like is this just level of how draconian we're stopped from bumping into each other? Like what other levers can policy makers pull?

KY: Yeah, I think unfortunately that's it basically. It can only be how much more lockdown we have at the moment. One thing that seems to be really important is getting this antibody test out to find out who's had the disease. So there was this talk early on from Boris Johnson about herd immunity. And so this is a mathematical idea really where if you have enough people in the population who are… who have had the disease and then are immune to it, then you can effectively wipe out the spread of that disease to the people who are more vulnerable and more at danger if they get the disease. And so actually there's a relationship directly between the basic reproduction number of the disease so how many infections one single infected person will spread to in the course of their infectious period and this ratio of how many people you have to have in order to get herd immunity and it's just one minus one divided by the basic reproduction number. So if the basic reproduction number is four then you have to have one minus a quarter or three quarters of the population immune to the disease before you effectively wipe it out. Ideally we would develop a vaccine so we could just get lots of people immune from the disease by vaccinating them but actually the alternative way to get herd immunity is by having disease. Obviously if every gets it then that's going to be awful but if we could get healthier demographics, younger demographics to have the disease, enough people to have it very mildly, that we could have that fraction of the population immune then potentially that's a strategy for taking the disease out. But in terms of what the government can actually do without putting huge numbers of life at risk, it's locking down further. Stopping people going out for exercise, putting road blocks in cities, stopping people from going on long journeys. So, yeah there's not much further we can go I guess but we could still go further. And unfortunately those are the only measures that are open to us without a vaccine at the moment.

BH: This herd immunity idea was quite controversial at the time though isn't it? 'Cause there is there sort of feeling of lambs to the slaughter, let's deliberately let our people get it for the greater good. And I sometimes have felt this way myself that sometimes when we talk about it all so mathematically we kinda forget that these are all human beings who are like suffering as a result. As a mathematician how do you feel about that because I see the pleasure you get from the model and the mathematics of it but at the same time there's this very human element to it?

KY: Yeah I think you're right, I think it was hugely controversial and it still hugely controversial and I'm not advocating this strategy of herd immunity that is one of a good way to go in this situation. Yeah I think that's partly why I decided to be a mathematical biologist in the first place because I thought I got to uni doing maths and I thought when's this going to be useful to people, right? And then I realized that actually you could use maths to describe biology and for me that was amazing because from a very early age I decided wanted to be a scientist. My mum died from cervical cancer and remember kids laughing at me at school when I was ten years old because I was like, I want to be a scientist, and they were like, I want to be footballer, I was like okay right. But yeah so like when I got to uni and did maths and found I could use maths to describe the real world and describe biology that was massive for me because I thought well I can actually have an impact on real people life and make a difference. And I think that's at the heart of all the modeling that we're trying to do is not to forget that actually these models describe real people. It's super important for us not to forget that.

BH: I mean it's seems pretty obvious that this pandemic's gonna leave a scar on the world and have some kind long lasting effect. What about mathematically? Do you think it's going to have a mathematical legacy? Is it gonna like, cause I've never seen mathematics talked about so much with a global news event.

KY: I think I hope it will draw people into mathematics and make people realize that you know if you become a mathematician you can have a real impact on the world, you're not just sat behind a desk writing a textbook for a subject which is dead and gone. You're actually living in the real world and you're doing things which can have a real important impact on people's lives so I hope that people, future generations of kids who are studying maths at school will say wow this is actually this living breathing exciting subject and I want to be part of that. And so I hope we'll get more people into mathematics and I also hope that people will take maths a little bit more seriously themselves. So maths generally only gets in the news when its the Fields Medalist times and you know people struggle to understand the very complicated maths that the Fields Medalists who have won the maths bowl but actually the moment we can tell people about relatively straight forward mathematical models which are having a huge impact on their everyday lives and suggesting how we have come to this unprecedented lockdown that we've never seen before. So yeah hopefully it will have a really big impact on people's lives.

BH: Kit is there a cutting edge here though? Is there new mathematics to be discovered and found here? Or is this basically pretty relatively simple mathematics and statistics just being applied in clever and new ways with more data and more tweaks? Is there like a discovery or new types of mathematics that a genius could come along and change things?

KY: I mean I have to say I'm a very sort of luddite mathematician. I like using tools that are already there. So I'm not working at the cutting edge of developing new mathematical tools. I like to know that someone knows that there's existence and uniqueness for certain problems but it doesn't have to me. So I'm probably the wrong person to ask that question to but…

BH: Yeah.

KY: But as far as I'm aware it's people applying tools in a new way. So it's tools that already exist, mathematical models that we've been developing for a number of years but actually applying them to new situations. Trying to get new insights from that.

BH: Can you just lastly just tell me a little bit more about this Royal Society project? What is this? Is this like all hands to the pump type thing?

KY: Right exactly, it's sort of like yeah… in Lord of the Rings when Aragorn runs in and says, you know, Gondor calls for aid, and everyone stands up says this is amazing. It's this call from the Royal Society, it came out over the weekend and they are asking people, mainly at Universities. Researching types of Universities to put proposals forward with their group and to volunteer amount of time can and what expertise they have including PhD students, postdocs and tenured faculty members to try and put forward their expertise and to offer it. And to hopefully try organize it. There's a lot of sort of individual modeling efforts people going off and doing their own thing. But actually we can work much better as a group as long as someone organizes us effectively and that's what the Royal Society are trying to do. So our research group, The Center for Mathematical Biology in Bath are putting together our proposal which we are going to send off tomorrow and we're going to contribute as much of our time as we can to help fight this.

BH: And I know it's just a proposal but can you just so I understand how you can even help, give me some vague ideas of to what that proposal looks like? What you propose?

KY: Yeah, so, yeah they're asking for ideas of what are your background expertise is and how you think that might be useful. So for me I have expertise in doing stochastic models, random models of multi-particle systems, multi-agent systems, so they're often called individual based models. And these can be really useful for understanding epidemic spread potentially at a very fine grained level. So looking literal interactions between people rather than thinking of everyone as this huge population in this S I R model. So that's the sort of thing that I'll be putting down. But we have other people in Bath who are traditional epidemiologists who have expertise in things like Household Models where you breakdown populations into households and you look at the effect of the different sizes of households and how people move between their local neighborhoods. There's all sorts of things that we're trying to do but that's the idea of the response in Bath at the moment.

BH: If someone was listening to this who wasn't a mathematician and is sort of following what's going on with the degree of fear and bewilderment but also interest, what do you want them to understand? What would you say to them if you could say anything to them?

KY: Right I think that if exponential growth teaches us anything about particularly about this disease spread, it's that the earlier you make your interventions and the tighter you do them, the more that you adhere to these rules that have been put in place, the bigger that you'll see this impact having within a few weeks, within even a few days it'll make a huge difference so now is the time to be so to speak doubling down on our efforts to lockdown so that we don't double up our number of cases if you'd like. So yeah really taking that exponential growth message to heart.

[gentle music fades in]

BH: Thank you for your time and hopefully you get involved in more work to help us all out.

KY: Great, thanks Brady it's been a pleasure.

[gentle music continues]

BH: Well that's it for today but I'm going to include some links to various resources and videos in the description for the podcast. Among them will be a video we did with Ben Sparks on Numberphile in which explained that SIR model. [music continues] You can find more about Numberphile at our website, that's numberphile.com or you can find us on YouTube pretty much by just typing in Numberphile. I'm Brady Haran, I look forward to catching you again soon and in the meantime please stay safe.

[gentle music fades out]