

Interview with Professor Hannah Fry HonFREng FIMA

*Hannah Fry is the IMA President for 2024 to 2025. She is a professor in the mathematics of cities at University College London. Hannah is an author and presenter, who hosts numerous podcasts and television shows, including *The Curious Cases of Rutherford & Fry*, *The Secret Genius of Modern Life* and *Uncharted with Hannah Fry*.*



Professor Hannah Fry

Congratulations on being chosen as IMA President. What are your plans for your term?

Oh, lordy. That's a big one to start with.

I think that everybody needs to just take a little bit of time initially to get a sense of things. So, I'm going to spend a little bit of time doing that, a little bit of time listening rather than talking.

We've entered this new era where mathematical tools and techniques are more important than they've ever been. There's been this seismic change in the world in the last decade or so with data and machine learning algorithms. And I think that now we have a lot of people who don't necessarily understand the nuances of this stuff, who are using them very widely. So, the communication of our subject has never been more important. Full stop.

... It's important to open out and be invitational to as wide an audience as possible ...

It's never been more important to open out and be invitational to as wide an audience as possible, while maintaining that credible grounding that you get from technical training.

What advice would you give to a mathematician who aspires to communicate their research to a wider audience?

OK, buckle up because I've got some tips.

The very first rule of communicating, before you do anything, is that you have to start off with who your audience is. What is it that they want? What is it that they know? And what is it that they're interested in? If you start off with identifying that, then you can plot a path to where you want to take them.

Almost always when I see communication done, it goes in the opposite direction. It starts off with people saying, 'This is what I want to tell people.'

Really good communication is not about you. It should never be about you, and it should never start with you. It has to start with the people you're talking to. And maybe that even starts with listening before talking to find out where people are. I think that's the absolute number one rule.

The second thing that's worth saying is that a lot of mathematicians think the public or non-technical people won't really understand or aren't really interested in big ideas. I've never found that to be the case. I've never once found a limit to the level of technical detail that people are interested in finding out. The only limit is their motivation to do so.

Let me see if I can give you an example. During the pandemic I was still recording programmes and so I would get taxis into town. Once when I was in a taxi, I had this really long conversation with the cab driver (who I'd never met before) about exponential functions, logarithmic axes and basically differentiation. Essentially, you know, like the rate of change and the rate of rate of change. We had this really long conversation about it.

Can you imagine me having this conversation with somebody where they're quizzing me about this stuff in 2019 or even in 2024? It would never happen in a million years, but during Covid a random person asked about logarithmic axes. There was a reason to care so he was motivated to understand, and then actually there was no limit to how much he wanted to know about it.

When you're trying to communicate technical ideas to people, you have to create a motivation instead of starting with the technical idea. I think that's really essential. You have to put in the work to get people to commit to listening to you. You have to get their permission. That's a better way to phrase it. You have to get their permission to talk to them, and that's something that's earned, right? Not demanded. I spend a lot of time thinking about how you do that.

Ultimately, I think right at the heart of it, every human is fundamentally the same. We all like surprise, we all like intrigue, we all like mystery, we all like humour and we all like wonder as well. If you can use some of the narrative storytelling tricks that appeal to every single person, then I think that you can very easily dress up technical ideas in a way that doesn't feel like you're just giving a boring lecture.

In your *Uncharted* podcast, which graph do you find most fascinating?

I really like all of them! There's loads of really good ones.

I really like the U-bend of happiness. I've got to be honest, it's not that technical, but I just love the idea that you find this pattern in humans. You find this signature. You come up with all of these explanations for it. Then you find it in orangutans. It's completely wild. It just throws away everything that you thought you knew. That's the stuff that I really love about this.

There are some occasions where there is nothing more articulate than a mathematical description and not just the really pure stuff of equations and calculus and really beautiful things. But the messy, gross data stuff that's all over the place. Just really hard to pin down.

But I still think that even then there are some occasions when nothing can get close to a mathematical description that really gets into the absolute heart of a problem and reveals something in a way that would otherwise be invisible.

In 2019, you were the first woman mathematician to give the Ri Christmas Lectures, following the first mathematician Christopher Zeeman in 1978. How important do you think that is for encouraging more girls into careers in mathematics?

I think the Royal Institution Christmas Lectures are this fantastic tradition. They are extremely engaging and the team who work on them are brilliant. I'm really glad that we still have them and it's a legacy that continues.

But I also know that the world has changed since Christopher Zeeman did his lectures, and that the ways in which young people especially get access to inspiring ideas is different. The more fragmented the audience, the less of an impact one intervention can have.

So, while Christopher Zeeman made a massive difference to loads and loads of people, I think that it is harder now to make that type of an impact from this single intervention. That's a big part of the reason why I don't see this role of encouraging young people as a one off. You don't get to cross the finish line, right? It's not like tick and well done, you're done.

There are people like Matt Parker in particular who has probably had at least as much of an impact as Christopher Zeeman had. And yet, he's done it in a much quieter way.

Brady, goodness me. Brady Haran from *Numberphile*. The impact that man has had is absolutely gigantic, but it feels invisible because it's happening on YouTube.

Whilst I was obviously extraordinarily proud to do the Christmas Lectures, I think the amount of impact that would have on young women is realistically quite small.

However, I think that the collective effort of a whole generation of mathematical communicators has been really profound. I do think that we are succeeding in changing the view of this subject, which as I mentioned at the beginning is particularly important given the moment that we find ourselves in history – with the advent of super advanced technology based on these mathematical ideas.

How important do you think the work you do is in broadening the appeal of mathematics?

I hope it makes a difference. It's really difficult to tell. I do get lots of amazing letters from young people and a lot of families as well. I always joke that my two main audiences are middle-aged men and teenage girls.

When panel show requests come in, I do think about them because I am stepping quite far away from my original intention of something (like documentaries) that is quite a worthy cause – actively changing the perception of this subject, which you and I both know to

be so much more, so much deeper, so much more joyful, so much more glorious than the average person thinks it is.

What I decided was that actually you're not going to change everybody's mind. Obviously. You're not going to suddenly make everyone in the country into mathematicians. But I think that if you can just have a positive association with the idea of a mathematician then that in itself can have some positive benefit.

And on those shows, what's the most fun you've had as a guest?

Oh my gosh. They're quite stressful!

I think I've worked out how to do *Have I Got News for You* now so that I can actually enjoy it. I went on *The Last Leg*. I've only done it once, but it was really, really fun.

I think that if you can get yourself into a state where you just see these events as though you are in a much lower pressure environment and can relax into them then they can be great fun.

Tell us about a cool bit of tech that has some surprising hidden maths?

I've recently made this programme – a new series on the BBC – it's called *The Secret Genius of Modern Life*. There's one episode about headphones, earbuds in particular. When you get a pair of earbuds that have got noise cancelling in them, the way that they work is completely insane. What happens is that there's a little tiny microphone that is on the outside of your earbuds, so you put the earbuds in your ear and then, let's say that I come really close to your ear and I clap my hands. That little clap will get picked up on the microphone and then it has to work out how to flip that sound around and play it into your ear.

But what essentially has to happen then is a race between the speed of sound and the speed of mathematical computation. The earbud has to calculate the inverse, add it to whatever you're listening to, and then at precisely the moment that that sound wave actually reaches your eardrum the speaker inside it needs to play the inverse of that sound. If they're even slightly out of phase, it's not going to work at all.

So, I think that there's this extraordinary, extraordinary thing in the distance across a tiny little earbud, that there is a race going on between mathematical computation and the speed of sound. Absolutely love that.

... a mathematical description that really gets into the absolute heart of a problem ...

... a race between the speed of sound and the speed of mathematical computation ...

Which mathematicians inspired you?

Oh my gosh. So many. Simon Singh's film about Fermat's Last Theorem and the book that accompanied it made such a huge difference to so many people, myself included. I genuinely don't know how many times I've read that book.

The life of a mathematician at the absolute limit is one where you are really pushing the absolute boundaries of what a human is capable of and that's the reason why some of the stories that Simon captured in his book were so captivating. The dogged, determined pursuit of your goal above anything else, I just find that very, very inspiring.

I love the story of Gauss. I think he's extraordinary. The fact that that man couldn't write anything down on a piece of paper without basically inventing a new area of mathematics is just unbelievable. I love all the stories of the crazy geniuses and the downtrodden. I don't know, the unlucky ones. I love all of that. The romantic history of mathematics, I think, is extraordinary.

Sophie Germain was a really, really gifted mathematician who worked on tensile stresses, but she pretended to be male in order to get tutoring from the École Polytechnique in Paris. She would write to Gauss, pretending to be a male and he had this whole correspondence with her. When she revealed herself to be female, he just thought she was quite an interesting mathematician. And I really like that.

But I also think that I'd never really intended to be a mathematician. It wasn't a big goal of mine. It wasn't a big life plan. I just enjoyed doing maths and then carried on enjoying doing maths and at no stage was I ready to give it up until one day when I woke up and realised, I was a professional mathematician. So, it wasn't like there was somebody who I was looking to and thinking that's who I want to emulate.

There were two people ultimately who made a really big difference to my mathematical career.

One is a teacher called Mrs Andrews, who I had from 11, all the way up to 16. She was very kind, very calm. She gave me a positive experience of the subject, to the point where it felt like it was more playful. The more playful something is, I think the easier it is to practise it and the more you practise it, the easier it is to become good at it.

Then the other one is Professor Frank Smith who is a Fellow of the Royal Society. He was my PhD supervisor, and he was just absolutely incredible. The most patient, kind, generous man who I think really helped to sculpt me and gave me a good example that I wanted to emulate.

What was your favourite mathematical topic in *The Curious Cases of Rutherford & Fry*?

Oh, I really like doing imaginary numbers. Just because they are lightweight enough as an idea that you can talk about it on the radio. You know, just go straight in and say this is what we're talking about. But if you really stop to think about them, they are a bit mind bending. This idea that there's this whole other set of numbers that no one knows about. That was very fun. A lot of people really liked that.

In your work as professor in the mathematics of cities, which of your mathematical models has the most surprising and diverse range of applications?

There's one really nice example from geospatial modelling where you have a source, lots of events and you're trying to work out where the source is likely to have come from based on where the events have happened.

So, you can think of it in terms of a serial killer. If I show you a map with lots of murders on it, you would be able to look at that map and have a pretty good guess as to where you expect the murderer to have come from. The problem is that if you're the police, you don't want a sort of hand-wavy way to do this; you want a much more rigorous analytical way to process the information.

The Dirichlet process, a mixture model, is a way to layer up these probability surfaces and hone in on where something is likely to come from. There's one particularly famous case about a serial rapist where it really helped the police to prioritise their list of suspects.

But the flexibility of it is extraordinary. There's a paper in Egypt that uses this kind of technique to work out where the stagnant water pools, which mosquitoes use as breeding grounds, are based on where cases of malaria have been found. One of my past PhD students did some work looking at where bomb factories are based on where improvised explosive devices have been found. There is also some work – which I think is very sweet – to find out who Banksy is based on where his paintings have been found.

I think that is a great example of just how powerful and flexible techniques can be when you really take the time to simplify ideas down to the absolute core of their mathematical structure.

You've said that your favourite data set is from Snowdon's Nun Study, so what makes it unusual?

David Snowdon managed to persuade 700 nuns to give him their brains. There is a room somewhere, I think it's in Kentucky, where you go in a basement and there's just row after row after row of nuns' brains in jars. Just extraordinary.

He was testing a study on Alzheimer's, but before these nuns died, he also managed to visit them over and over again as they aged. He would give them what's called the Mini Mental State Examination. It's essentially like testing how sharp their brains were; how many words they could remember in a minute, what capital cities they could name, that kind of thing.

There's this one graph which shows the performance of these nuns as they age, so each nun appears on this graph more than once and you see this steady decline as they slowly get older. There's that clear pattern. But there's one really extraordinary dot that appears on this graph and it's way, way over on the right-hand side, right at the top and it's a dot that belongs to a woman called Sister Mary.

Sister Mary died when she was 101 and she was absolutely sharp as a pin. Super on it, even all the way up until she died and no signs of dementia at all.

... where you are really pushing the absolute boundaries of what a human is capable of ...

... to simplify ideas down to the absolute core of their mathematical structure ...

Anyway, the team – after she passed away – opened up her brain and had a look inside it, expecting that her brain had been completely resilient and that no dementia at all had occurred. But when they looked inside her skull, they found this brain that had all of the hallmarks of having been completely ravaged by disease. She had these huge plaques in there. She should have been way less capable than she actually was given the state of her brain.

I think this study was the beginning of the research into cognitive resilience, into this idea that if you practise – word searches and chess and all of that kind of stuff – then you can actually mitigate against some of the worst effects of dementia.

The other unbelievable thing about this study is that they found the essays that all of these women had written when they entered the sisterhood, when they were 17, 18, 19. In these essays, which are all sort of personal statements, it turns out that if you look at the complexity of the language – sentence structure, how densely packed the ideas are, all of that stuff – then you can predict who will go on to show symptoms of dementia later in life. Even though these essays were written literally decades before any of these women got old enough to experience any dementia at all. I think it just tells us how much there still is to learn about dementia.

But also, what an unbelievable act of generosity by those women to give us their brains. And to take part in this study and to really, I think, leave a gift for all of humanity in how far we understand the effects of dementia.

What role do you think algorithms play in a Bayesian world?

That's a good question. Did you know that's the subject of my new book?

If we really stop to consider it, all of us know that absolute certainty is impossible. Perfect prediction is not something that exists. Absolute yeses or nos are not a thing. I think we all know that. And yet we have this tendency to default to binary choices, yes or no, true or false, swipe left or swipe right.

I think that what's happened is, as you include algorithms in this Bayesian world, it's encouraged us to go further into seeing things as though they're binary choices.

Dating apps are a perfect illustration of this. When you meet somebody for the first time, the whole world is one of maybes. Everything that's in your mind is maybes. Maybe they're this, maybe they're that – it's all uncertainty and it's all Bayesian. You're going to update that as you go along.

What happens is that when you put an algorithm in that environment, you can't have any of that nuance. You can't have any of that uncertainty. It all has to be stripped away and all you're left with is just a yes or no, swipe left or swipe right.

But I think that you're left with an experience that we're all the poorer for. Our collective experience of our romantic partners in the modern era is not as rich as it once was because of that process of filtering things out. I think that the algorithms that we have are having this really big impact on us. Fundamentally there's not enough room for randomness. I

... Perfect prediction is not something that exists ...

... there's not enough room for randomness. I would like to see a bit more noise. ...

would like to see a bit more noise.

When you see other people's profiles, you're presented with people who meet your criteria, and at that point you have to decide whether you want to match with them or not, and so you say yes, no, yes, no, yes, no, yes, no. And if they say yes to you as well then you match and you can talk to each other.

I found this couple in Germany who, basically, she accidentally swiped the wrong way. She meant to swipe no, she accidentally swiped yes and now they're together. I think that they're probably going to get married.

If you think about the people in your life who you have had the biggest crushes on, the people in your life who you think, 'Yeah, I really like that person'. Are they a perfect match for the criteria that you would put into a dating app, especially if you thought that there was an infinite number of possibilities available online. Almost certainly not. I think by changing something into an algorithm, you're stripping away a lot of the noise that actually gives rise to much of the richness that humans revel in.

The other thing that's worth saying is that historically we've expected our computers to be instruments of precision. To give you an example, if you had a calculator and you put the same sum in twice, you would expect to get the same answer every time. A word processor works in reliably identical ways every single time. And I think that is how we've expected our machines to be.

But the thing is that what we're now doing with machine learning, algorithms and artificial intelligence is we're moving. That whole revolution is one where they have embraced the Bayesian worldview and made it much more about probabilistic frameworks rather than deterministic ones.

I think we're yet to change our mindset. We still expect that an algorithm, if it says yes or no, then that is the answer. Even though the yeses or nos that we're getting now come with caveats.

There's something a little bit dangerous about that too. I think that we struggle with critical thought, and we have a habit of deifying the output of algorithms. Just because we're not remembering enough that we're all living in a Bayesian world.

Do you have any mathematical hobbies?

I play chess. That's a recent thing I'd say. I'm not very good yet but boy am I competitive! I've got really addicted to it. I basically play every day now.

My dad made me a chess set when I was a kid out of plaster of Paris. I got it set up in my house. A friend of mine is making me a really beautiful chess board, but from walnut and maple wood with all the knots in the grain. That's going to be my present to myself. I'm going to sit there and I'm just going to play chess for days and days and days.

Rebecca Waters
Editorial Officer