Numberphile Podcast Transcript
Episode: Champaign Mathematician - with Holly Krieger
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From Illinois to Cambridgeshire, Holly Krieger's path to mathematics was an unusual one.

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[gentle piano music]

Brady Haran [BH]: Today's guest is Holly Krieger. A lot of Numberphile viewers will know her from numerous popular videos on our Youtube channel. Especially ones about her beloved Mandelbrot Set. [music continues] Holly's an American mathematician but she's now working at the University of Cambridge in the UK and her path to mathematics, well, it's not as direct as you might expect.

[music continues]

Holly Krieger [HK]: I was born in Champaign, Illinois.

[music fades]

BH: Champagne?

[music fades out]

HK: Yeah, spelled differently than the proper Champagne. [laughs]

BH: How's it spelt?

HK: C H A M P A I G N.

BH: Do they have a special drink there that can only be made in the area, or…?

HK: Heh, yeah but it's made in barns out of [laughs] leftover corn, I mean… [laughs]

BH: [laughs]

HK: So, no, it's a university town, so there is so town there but it's pretty rural.

BH: And what were you like as like a little girl?

HK: Loud and obnoxious, is that what you're gonna… yeah, no, I think I was normal. I mean there's this phenomenon where the way you remember yourself has nothing to do with the way that other people remember you.

BH: Right.

HK: And so when I was small I mean I thought of myself as like, quite outgoing and you know, like to have fun, but in reality I think I was like a little nerd.

BH: Right.

HK: Who, kind of tagged along with adults when she wasn't wanted and… [laughs]

BH: Would I have guessed you were going to become mathematician?

HK: Oh, I really… you've pinned me down by asking the question that way. [laughs]

BH: Right? [chuckles]

HK: I was back visiting ten years after I graduated high school for a band reunion. So… that's already partially answering your question. [laughs]

BH: Right?

HK: [laughs]

BH: [laughs]

HK: And at the time I think I had just gotten like my first post PhD job, this like postdoc at MIT. And I went there and I was really expected everyone to be like shocked that in the end what I had done was go get a PhD in mathematics and like do this super nerdy academic mathematician thing. And then when I got there everyone was like, oh yeah… yeah we could tell when you were in school that was the kind of thing you would end up doing. And I had thought like, I

would be, you know, a rock star or something. I dunno. [laugh]

BH: Okay so you didn't…

HK: Not really but you know.

BH: So you didn't aspire to be a mathematician when you were…

HK: No! Not at all. Quite the opposite. Like first of all I didn't know it was job until I was probably in graduate school I would say. Like I didn't understand what research mathematics was and what that meant and then the other thing is just it wasn't kind of the group that I identified with as a kid. I think I went to one meeting of math team, [laughs] when I was in my first year of high school. When you're a twelve year old girl and you're kind of nerdy, social acceptance is like a really high priority. [laughs]

BH: Right.

HK: And so after my first meeting of math team I was like, well, I think like I don't really wanna belong to this group. I, you know, I wanna talk to different people and I want to sort of be more… be more sociable and be in… be in a different group. So it was a very sort of, first of all very judgmental [laughs] twelve year old girl which… is not super surprising I suppose, but really it was like a conscious decision on my part that even though science and math was stuff that I was good at and I found fun, that I didn't really want to direct as much energy that way as I could.

BH: Do you think it held you back from being even better at it? At that young age? Like if you'd hung out with those kids and had you would have, you know, become even better at high school or did you… were you still pretty good at it despite shunning them?

HK: [laughs]

BH: Shunning math team.

HK: My judgmental anti-math position.

BH: Yeah, yeah.

HK: Umm… I'm sure I would have been better at it just from practicing and being surrounded at it. Surrounded by it rather. But I'm not sure that that's like… something that would have changed my life for the positive in anyway. I mean we put a lot of pressure on sort of performance in school and that kind of thing and it's a means to an end, not a thing in and of itself and so in fact I'm really happy with the way I sort of circuitously came around to becoming a mathematician.

BH: So if I went back in time and asked little Holly… like what'd'you wanna be when you grow up? What kind of answers would I have got at different points.

HK: [laughs] Oh that's a good question. Okay, let's see, so when I was young I… the two main things that I wanted to do, I think, when I was really young I wanted to be an astronaut which is, you know, sciencey but I was in it for like the see the Earth from the Moon type of adventure. [laughs]

BH: Cool. Yeah.

HK: I still kind of wanna be an astronaut by the way. [laughs] But I think I'm aging out at some point.

BH: Right.

HK: So I wanted to be an astronaut, I wanted to be a singer, so I sang. My mom sings.

BH: You've got a microphone in front of you, Holly. This is your chance.

HK: I haven't sung for a very long time. [laughs]

BH: Alright. [laughs]

HK: [laughs] The fear that any of my colleagues might hear such a thing… will definitely prevent it.

BH: Okay.

HK: So I was interested in like performance type things also in school and I did think about doing that. I played the trumpet quite seriously in school and I thought about going into that. My uncle is a professional trumpet player.

BH: Do you still own a trumpet?

HK: I do still own a trumpet, yeah. And I've picked it up a few times.

BH: When was the last time you played the trumpet?

HK: Umm… just a month ago, or so! I'm working on a piece because I might audition to join an orchestra.

BH: Cool!

HK: [laughs] I like it but the problem is, you know, trumpet in orchestra you play like once every ten minutes and [laugh]

BH: Oh okay. Right.

HK: So we'll see.

BH: So at what point… did like… did it switch and you realized, oh I think I'm gonna end up doing mathematics at university, yeah?

HK: Oh so it was like late in university when I switched into maths.

BH: Oh, right?

HK: So I had started in biology.

BH: You said maths!

HK: Well eventually.

BH: No you said maths [hisses] with an S.

HK: Oh! [laughs]

BH: You've been…

HK: I don't even notice anymore.

BH: You've been anglicized.

HK: Well, partially.

BH: I'm the opposite. I'm the opposite.

HK: You say math now?

BH: Yeah.

HK: I think I switch. It's basically like the maximum confusion level. I switch flexibly between math and maths. And zee and zed. That's a big one for me.

BH: Okay.

HK: Because like I try to give my students a break… by learning to speak with zed instead of zee.

BH: Yeah.

HK: Because I use it as a variable all the time when I teach.

BH: Yeah.

HK: But it's not quite sunk in. [laughs]

BH: Do you give people your mobile number or your cell?

HK: [sighs] That one… that one I use cell unless I'm consciously thinking about mobile.

BH: Okay.

HK: But mobile sounds weird to me because not only is it the different word for it but it's pronounced differently than in an American accent.

BH: Ah mobile [mo-bull]

HK: And so there's like the double hit of the change, so…

BH: Yeah, mobile [mo-bull] mobile. [mo-bile]

HK: [laughs]

BH: Anyway, you were saying, so you didn't go to university to do mathematics.

HK: No, I went to do biology initially. I was interested in genetics and the problem was, so I was in biology for like, I think a year and the problem was that there was a chem lab eight AM on Fridays.

BH: [winces]

HK: And like… I got to university and I realized that there was, you know, a lot of interesting things to learn in biology and chemistry and also a lot of interesting bars to go to. [laughs]

BH: Okay. Right.

HK: And those two goals were sort of incompatible. [laughs]

BH: Okay.

HK: And so… no I mean I'm joking.

BH: [laughs]

HK: I just didn't like chemistry.

BH: Yeah?

HK: And I didn't like being in the lab and lab work in particular I was like not interested in.

BH: Because you were good at it, didn't have an aptitude for it or you just… something you didn't like about it?

HK: I don't know how to answer that question 'cause I think they're so closely related, right? Like there's kind of a feedback cycle of you're initially kind of not so good and then you lose interest and then it goes back and forth, you know it gets worse and worse.

BH: Okay.

HK: So hating lab work I switched my major into psychology and I tried that for like… one or two semesters. And the problem is, and I'm gonna get in trouble with a lot of people here, they just make all the stuff up. [laughs]

BH: [laughs]

HK: [laughs] Right, like? [laughs] I was learning some like intro…

BH: Send all your emails to Holly.

HK: Yeah that's right, don't blame Brady. I was learning all this stuff in Psych 101 and Psych 201 and all of this neuropsychology stuff and I just didn't believe it. You know it wasn't convincing evidence to me and so it made me worry about sort of the value of what I would be doing if I pursued a degree in Psych.

BH: Hmm.

HK: So… then I switched to something more valuable, which was Italian.

BH: Oh god.

HK: [laughs]

BH: It would have been quicker to ask you the list… list the things you didn't do. [laughs]

HK: Yeah it's true, it's true. [laughs]

BH: Italian? Alright.

HK: Italian, yeah.

BH: Why Italian?

HK: Oh I really hate to tell you all of my justifications. This one is the worst. So I had to take some language requirement at my university and I wanted to take Portuguese, but the class was full so I took Italian instead. [chuckles]

BH: Okay.

HK: The professor was attractive so I took more Italian classes. [laughs]

BH: How long did you do that for?

HK: Only I think a semester.

BH: Okay.

HK: So then I decided no one's gonna ever pay me for my Italian degree so I want a job that pays something.

BH: Yeah.

HK: So I switched into computer science.

BH: Right. [chuckles]

HK: [laughs] Okay this story's almost over.

BH: Yeah?

HK: So I'm in computer science and I have to take some Introduction to Proofs class in mathematics.

BH: Right.

HK: Because it's one of the requirements for CS. Again because of like scheduling randomness I ended up in the Honors section of the Intro to Proofs class.

BH: Okay.

HK: And it was really fantastic. And it was sort of like the first time when I had made… so this is a thing that I get to still experience and is a lot of the reason why I'm in this field still, which is I got to experience that transition from totally not understanding something, like being completely lost, someone explaining it to you, you know, possibly over and over again and still not having it get… into your brain. And then suddenly one moment… you just get it. It just clicks. And then forever after you are able to understand it. And so I had this phenomenon with a piece mathematics in that course.

BH: Do you remember what it was?

HK: Yeah, it was [laughs] it was the Bolzano-Weierstrass Theorem. So it's this theorem that says if you take a collection of points, say… let's say real numbers between zero and one, okay? If you have infinitely many of them, then there must be some limit point that they… they accumulate to.

BH: Okay.

HK: So, I'm trying to think of a better way to describe that, it's essentially saying that, if you have infinitely many points in like a closed box [laughs] that there has to be some point which is well approximated by them. Anyways… it's just some like little…

BH: Now where is that point between zero and one?

HK: Well it depends on the infinite set of points you start with.

BH: Okay.

HK: So if you think about the set of points one and one half and one-third and one-quarter and one-fifth and la la la, that's an infinite set of point that are between zero and one.

BH: Yeah.

HK: And they accumulate at the point zero. So the theorem itself is not telling you where the point is, it's just telling you that it exists.

BH: Okay.

HK: But for some examples you can figure out what it is.

BH: So those other… I can't even remember them all now, those other subjects

you did at university, none of them had that, gave you that…

HK: No.

BH: That thrill.

HK: No I mean to be honest at the time… what I was looking for was like what's a degree that is sort of like minimal effort. [laughs]

BH: Right.

HK: And maximal outcome…

BH: Yeah.

HK: …and it was a very like, cost benefit analysis to look at university which I think is pretty common actually and not something that we talk about. We talk a lot at least on the faculty level. We talk a lot about like passion for subject and that kind of thing and that's not really how a lot of students make their decisions and I didn't either because I just hadn't experienced it for the first few years.

BH: So when you have this moment, you're actually currently enrolled in computer science.

HK: Mhm.

BH: You then jump into mathematics for more?

HK: Yeah. Yeah. So the next term instead of taking this like hodgepodge of coursework that I had been doing I took four advanced maths courses. Now I'm like self conscious about math versus maths. [laughs]

BH: [laughs] During this period where you are like, you know, keep changing horses…

HK: [laughs]

BH: …how were the people in your life reacting to that? I'm just curious, like your family and that…

HK: [laughs]

BH: …were they like… were they worried about you or did they think this was really good that you were so like proactive in changing? What kind of advice and feedback and reaction where you getting from those around you?

HK: That's a great question, so they were not like, congratulations on being proactive. [laughs]

BH: I was being nice. I didn't really think they would do that. [laughs]

HK: [laughs] That's a very supportive family.

BH: Yeah. [laughs]

HK: I think they were not that worried because like one feature of my personality that has been sort of constant since I was quite young is… a high level of independence.

BH: Right.

HK: And so I think, you know, they had some knowledge that whatever it ended up being I would come through with some level of competence and independence and…

BH: And it wasn't like you were flunking out of these things, you were just… you were making…

HK: Right, right.

BH: …the decision to change.

HK: Yeah exactly.

BH: And then math was like, you found your home and you didn't feel like you wanted to move anymore.

HK: No for the most part since then I've been happy.

BH: Okay. [laughs] for the most part.

HK: For the most part.

BH: For the most part.

HK: Well some of the decisions have still been accidental I think. For example deciding to apply to graduate school. It seemed easier than applying to other jobs.

BH: Because I was going to say, you were saying you were looking for something that would not involve too much effort.

HK: [laughs]

BH: But also give you like… an income at the end.

HK: Yeah.

BH: Like, mathematics is not the obvious choice. Like is that when you abandoned that ethos and thought I'm gonna do something for the love of it, or did you see an income at the end?

HK: I think that if at any point I had stopped seeing like a practical future for myself that I probably would have switched.

BH: Okay.

HK: Yeah so I did keep that practicalities in mind still because I think like this is a really big motivator for me is that I want to have a nice life outside of work which is funny given that you just asked me what I'm gonna do over the weekend and I said I'm gonna work.

BH: Yeah. [laughs]

HK: [laughs]

BH: Yeah.

HK: But… no in reality like the flexibility of the job and that kind of things I view as compensating for the fact that it's not, you know, going to write code for Google or something. It's not going to, you know, make a pile of money ever for me. [laughs]

BH: So when you were doing mathematics at university, did you imagine… in the end oh I'm gonna end up working in Wall Street, or did you think I'm gonna end up being a researcher mathematician?

HK: To the extent that I thought about it… it would be research

mathematician.

BH: Okay.

HK: Yeah.

BH: Alright.

HK: Yeah, because I already knew that I was really interested in this feature of academia which is… like the level of independence that you have. Not having a boss telling you what to work on, I could already see was like a high priority for myself.

BH: PhD was almost a given then… you were always thinking alright…

HK: [laughs]

BH: …after I… when I graduate I'm gonna do a PhD.

HK: I again think we're giving twenty year old Holly like a little too much credit for foresight. [laughs]

BH: Alright.

HK: Yeah when I thought about it, like when I had to make a decision about what do I do next then yes, I chose PhD. I didn't apply to any external jobs. I just applied to academic jobs. PhDs in particular.

BH: Yeah.

HK: But I really would not say that like I sat down as an adult and thought it through well. There was a little bit of sort of careening about.

[gentle violin music]

BH: What was the gender mix of your math class when you finally settled on mathematics?

HK: [laughs]

BH: Was it like a good mix. Was it lots and lots of guys, or…?

HK: Because I had done this honors Intro to Proofs class, they moved me to the honors section of the maths undergraduate cohort.

BH: Yeah?

HK: And that was pretty small. I think it was just two of us out of… sixteen or fifteen or something like that that were in the group of honors mathematicians.

BH: That were women.

HK: That were women, yeah.

BH: Did that have any effect or impact of do you have any thoughts on it, doing like going through and doing a degree in such a male environment? Or did just… didn't make a difference? It just brushed over you?

HK: At the time I don't think it had very much of an impact. I became good friends with the other woman in the program so there was some positive interaction.

BH: Yeah.

HK: The only like sort of negative thing at that level for me was just that there was just some discomfort occasionally in the interaction, you know, I didn't get along that well with a lot of the other people in the program, not because I don't get along with guys [laughs] but because you know our common interests were just a lot less likely to overlap and… it wasn't so easy to talk them and stuff like that. So but no, I would say… like at the time I was really not very conscientious about being in the minority or anything like that and in particular like I was also quite keen to avoid being put into a box of you know minority mathematicians in that way, right, like… you know if they're taking some photos to be like oh here's the maths department and it's like somehow the women are always in the photo, you know? [laughs]

BH: Yeah.

HK: That kind of thing I really fought against when I was an undergraduate because I wanted to be viewed for my mathematics and I didn't wanna prioritize having to think about this other thing.

BH: At what point did you start gravitating towards a certain field or part of mathematics, like, you know a specialization?

HK: So I did that pretty early, but I did change a little bit in that too, though I won't go into the full list for you. [laughs]

BH: Alright, I imagine… [laughs] imagine my shock.

HK: Yeah I know. [laughs]

BH: [laughs]

HK: So that is a little bit more like follow your heart, I think. [laughs] Which is that, you know, you're taking courses and you just identify… you just identify

with ones you find fun and easy… not easy but… that make sense for you and that's just the track that I followed for the most part.

BH: Right.

HK: There was a little bit of active choice when I was in the middle of graduate school, about which subfield I wanted to be in. Which had a lot to do with sort of the people in the field and like who I wanted to spend the next 50 years interacting with and kind of the attitudes in the field that lead to me ending up to choose the field that I'm in.

BH: That seems to be such a thing from a few of the people I've spoken to. Like, as much as having an affinity and a passion for the… the mathematics. It's like the people, like a few charismatic people or inspiring people or just a good group that you want to hang out with.

HK: Yeah.

BH: Sometimes makes a big difference.

HK: Yeah it does, and to be honest I think that's the way it should be, right? I think that someone who is sort of like at the professional level or PhD level or whatever, should be able to sort of move fluidly between areas of expertise given enough time. And so the more important thing is to choose people that you actually can imagine being around for the next [chuckles] fifty years and people who inspire you.

BH: I wonder if there are certain areas of mathematics though that get neglected because of… a few… grumpy old mathematicians.

HK: Absolutely.

BH: There are? Can you name them?

HK: Uhh. [laughs]

BH: [laughs]

HK: I could. [laughs]

BH: [laughs] So and tell me about the area you did move to and you've… where you ended up.

HK: Yeah so in the end I'm in a field called arithmetic dynamics. Which is basically those two pieces put together [chuckles] so it's arithmetic, number theory, so the study of prime numbers and integers and that kind of thing, and dynamics which is the study of iterating systems. So like for example thinking about like the solar system. We know where everything… let's leave the subtleties out of it… we know where everything is right now.

BH: Right. yeah.

HK: And so it's pretty easy to predict where everything'll be a minute from now.

BH: Yeah.

HK: What if I just said, I've just said that it's easy to go from like time zero to time one minute, in terms of prediction, but then if we take the rule that takes us from time zero to time one and we apply it over and over and over again, if we iterate the system…

BH: Hmm.

HK: …then eventually it starts to become hard to understand and complex.

BH: I can see what that happens with the solar system 'cause of…

HK: Mhm.

BH: …'cause there are so many moving parts and little things that can wobble and some rogue comet can come here and this and that and… but I would've thought the one place that wouldn't happen…

HK: [laughs]

BH: …was mathematics. Because you've got a fixed point…

HK: Mhm.

BH: …where you start and nothing can move and nothing can change, 'cause it doesn't even exist, it's an abstraction so… so like what… how can there be anything that mathematics can't predict?

HK: [laughs] That's a really good question. So this is like the heart of the kind of thing I study, which is about this notion of chaos.

BH: Hmm.

HK: So lemme explain a little bit about what I mean. I mean it's basically [chuckles] like, you know the description that Jurassic Park where he's kind of hitting on Laura Dern and he explains chaos by dropping water on her hand?

BH: On her…

HK: Do you?

BH: Yeah, yeah.

HK: It's not a terrible description. [laughs]

BH: Right.

HK: So like what is a chaotic point for a dynamical system? It's not one where you don't know what happens to the point. It's a point where you don't know what happens if you wiggle the point around a little bit. So if you think about…

BH: Ohh.

HK: …like what does it mean to be a chaotic point, I'm not saying, oh I never know what happens to this point. I'm saying that the kind of long term behavior can change depending on if I wiggle it a little bit to the right, a little bit to the left, a little bit up a little bit down.

BH: Okay.

HK: And so it's failure of… like… like…

BH: How does…

HK: …stable behavior nearby.

BH: How does tweaking the initial parameters affect what happens next.

HK: Exactly, exactly.

BH: Where'd you do your PhD?

HK: Illinois, but Chicago.

BH: Okay.

HK: Yeah.

BH: And then like… and then what? What happens when you finish PhD. I've heard of this… what's it called? Postdoc trap or something? Where you just end up being a postdoc forever?

HK: [laughs]

BH: Like…

HK: That does happen.

BH: Yeah.

HK: Fortunately not to me. I did do a postdoc.

BH: Yeah?

HK: So after my PhD I went to a postdoc at MIT. These are like these three year stints where it's meant to be like okay, in three furious years you're gonna prove to everyone that like you're a good investment for a permanent job. [laughs]

BH: Okay.

HK: Alright, so you do as much research as possible. You meet as many people as possible, that kind of thing.

BH: Yeah.

HK: And so you're right, that it's becoming more and more common to struggle to move directly from your first postdoc into a permanent faculty job but I was able to do that.

BH: What are those three years like then, where you're kind of really having like… is that like you're putting yourself on the market it feels like? That must be really stressful.

HK: It is. it is. And you sort of… even though there are other postdocs around, you don't have a community in the same way that graduate students have a community and faculty have a community because everyone knows that… you're leaving soon. [laughs]

BH: And also there you're rivals.

HK: And… yeah they are your rival… I guess I didn't really think of it that way. I mean… of course you're right [laughs] but there's not a lot of like mathematical sabotage going on. As far as I'm aware, I mean. [laughs]

BH: Okay. Right.

HK: And so… it's a little bit less direct rivals than… than some other fields where you're sort of like rushing to publish all the time.

BH: Yeah.

HK: It's a little bit lonely. [laughs] I think, that's the first thing. You feel really isolated. It's hard personally, right? Like, you know you're moving and so you've just moved and you know you're moving again it's hard to sort of settle and you know, if you have a partner or kids or whatever, it's even harder.

BH: Isn't there a chance you'll end up getting a permanent job where you postdoc, though? Like isn't that almost like wouldn't that be like your goal like 'cause they're the people who know you best and see you all the time so if you're impressive it feels like that would be one of the more likely places to employ you?

HK: So it happens, but it's not as frequent as you might think. So one of the issues is that there's more postdocs than permanent positions and so there's sort of like a filtering effect as you go along, right?

BH: Yeah.

HK: Just like there's more graduate student places than postdoctoral places and so the type of institution where you're like to be employed changes through the course of your career.

BH: Yeah.

HK: And then the other thing is that there's some sort of specific reasons why that might not happen.

BH: So where… what did happen when you finished your postdoc at MIT?

HK: So what happened when I finished my postdoc at MIT is I got this job [laughs] in Cambridge.

BH: Alright, and what is your current job then? 'Cause we are sitting in your office.

HK: [laughs]

BH: Your… pretty nice office by the way.

HK: [laughs]

BH: I've met a lot of mathematicians who I think are more senior than you that don't have offices this nice.

HK: [laughs]

BH: So… you've done really well. Lovely corner, windows everywhere.

HK: I do like my office, it's true. [laughs]

BH: Yeah? What is your job here?

HK: So I'm a lecturer here, so the American equivalent would be like an Assistant Professor, which is the first level of professor essentially. [chuckles]

BH: Okay.

HK: So it's a permanent job but, you know, I still have steps to go here. So here they're called, you know, reader is the second position and then professor is the final title.

BH: Okay. And what… so what are your responsibilities? You obviously have to teach.

HK: I do.

BH: But you still research as well?

HK: Yeah. Yeah.

BH: So how does that… what's the mixture of that and how does all that work?

HK: So it's a little Cambridge specific, our terms are short here and so the teaching is like very intensive [chuckles], so for the most part what I do is I don't usually get much done research-wise when we're actually in term with the students around.

BH: Yeah.

HK: But because they're shorter that means that I do have other times of the year when I can focus on research.

BH: Are we in a teaching or a research period at the moment?

HK: We just transitioned from research to teaching.

BH: Oh no.

HK: [laughs]

BH: Do you have to be in class soon? Am I keeping you?

HK: I do… no not yet today. It's gonna start on Thursday.

BH: Oh dear.

HK: So… which I had to ask my colleagues… classes in Cambridge start on Thursday and I always forget so. But no that's why you see these piles of papers. These are all projects. [laughs] Each pile is a project that I've worked in recent months that I swore to myself I would finish by this time that I have not finished

by this time.

BH: So these shelves I'm looking at are your research shelves?

HK: You are.

BH: Tell me what research looks like. So if you said, oh this is brilliant I've got all day today to do research…

HK: Mhm?

BH: …what do you do? Like, do you just sit at a table? Do you go for a swim? Like…

HK: [laughs]

BH: Like, how do you… 'cause presumably when you research the whole point is to have like a new idea and a new way to do something.

HK: Yeah.

BH: How does one have an idea? What does this look like?

HK: Oh man… I don't know. [laughs]

BH: [laughs] If I say, Holly you can have all day to do research.

HK: Mhm.

BH: Tell me what happens from when you wake up.

HK: Okay so… if I have all day to do research, what happens when I wake is

the same as other days which is that I read my phone in bed for like an hour. [laughs]

BH: Okay.

HK: [laughs]

BH: [laughs]

HK: And answer some emails, you know, boring stuff.

BH: [laughs]

HK: But once I get here and I start thinking, usually it's not the idea phase that I would work on by myself in my office. So, maybe maybe like some really specific piece of a proof I'm working on that needs some new idea or some new input. But for me research is very writing intensive, so I'm kind of trying different things and doing computations and trying examples and seeing if I can extract sort of what's really going on [laughs] in the thing that I'm trying to prove, and on a good a day it works and on a bad day it doesn't work and on a really bad day it works until like nine PM and then I realize that I made a mistake. [laughs]

BH: Are you using paper and a pencil?

HK: Yeah, yeah.

BH: Are you on a computer or…?

HK: Paper and pen.

BH: Yeah?

HK: Yeah, like gigantic mountains of paper [chuckles] and pen.

BH: Right, and just like are you like throwing things all over the floor…

HK : [laughs]

BH: …is it like… are you writing on windows and…?

HK: I have not yet done either of those things but now it sounds kinda fun so maybe I'll try it. [chuckles]

BH: Okay. You said that's not the idea phase. What's the idea phase?

HK: Yeah, so the idea phase for me at least… it does happen sort of thinking in solitude occasionally, that sort of put some pieces together that I didn't realize were connected before but that is what I consider an idea mathematically by the way is like combining things that you already know reasonably well in a new or interesting way. So to me like that's the innovative part. But where that usually happens for me is often where I'm introduced to something new which would be like at a conference or a colleagues talk or something like that and I see something that I recognize, right? Like they're speaking about something that I don't know anything about and I'm trying to learn but some piece of it rings a bell with something else that I know and I then try to think about like… hmm, well what if we… took this question and changed it just a little bit in a way that I might be able to say something? And so that's the most common form that like a literally new idea takes is I'm introduced to some new technique or some new proof or something like that and I see how it relates to some other piece of mathematics and try and extract value from that.

BH: What do you do when that happens? Like what's your first course of action? Do you… do you rush up and see that person after the lecture, do you

keep it to yourself in case your wrong…

HK: [laughs]

BH: …and go and have a play on your own and have a look through it, or… what do you do when this possibility suddenly presents itself?

HK: It actually depends a lot on the person. So we were talking earlier about like personality matters and this is one of the ways. If it's someone that I trust and someone that I know isn't gonna be like, wow, that's a really stupid idea, if I have made some mistake…

BH: Yeah.

HK: Then yeah I just rush up and tell them like, have you thought about like this direction of it and whaddya think about this and would this work and do you see any reason why it wouldn't? That kind of thing and it's quite exciting and fun and of course it's better in terms of the speed of progress is much higher when you're working with someone else and have someone else to bounce ideas off of. But it certainly has happened that I've been in this situation and maybe not had such a good impression of how that would go, in conversation with the person and then I keep it to myself and I think it really through carefully and I sort of complete the argument myself and know that it's solid before I get in touch with anyone else about it.

BH: In your field at the moment, is there like… a big white whale? What's the big… what are the big things in your, you know… what would win the big prize in your field at the moment? Is it something I will have heard of?

HK: So one of the big things in my specific field that is still open that people are really interested in is called the Uniform Boundedness Conjecture.

BH: Oh, which we just made a video about.

HK: Which we just made a video about. [laughs]

BH: Half an hour ago.

HK: [laughs]

BH: Yeah. I know all about that!

HK: Yeah, and so now you know about it so you can start working on solving it. [laughs]

BH: I think I've already forgotten. [laughs]

HK: [laughs]

BH: We're well beyond my event horizon of remembering.

HK: [laughs] Anyway, so just… it's an example of a broader class of mathematical problems that ask about how arithmetic, like prime numbers, interact with dynamics. And trying to understand and connect it to all these questions of like geometry and all these different fields of mathematics of what can we say if we have a mathematical object that we can look at from two different angles. Say like a dynamical angle and a arithmetic angle, how do the two perspectives connect to each other?

BH: Hmm.

HK: And so that's just like sort of a vague description but even thought it's vague this description has led to a lot of questions in mathematics that… that are really interesting and those types of things are the kinds of things that I think are

most interesting to my field right now.

BH: Does every mathematician hope that that'll be the person that does it? Like do you hope you'll be the person that does it or is that now how mathematicians think or…?

HK: That's how some mathematicians think. And I think that those are the people who usually do end up doing those kinds of [chuckles], right, like if you make it a really high priority, like, I have a white whale, I have a problem I'm gonna thinking about everyday for the next ten years.

BH: Yeah.

HK: I think you're likely to make some progress on it, right?

BH: Yeah.

HK: Personally, you know… I don't really care that much [laughs]

BH: What…

HK: [laughs]

BH: I was gonna ask though, I mean you especially… well you were at MIT and now you're at Cambridge so you spend a lot of time surrounded by like superstars of mathematics, right?

HK: Yeah, yeah.

BH: You know, Fields Medalists and all sorts of people. What do you want? Do you want like… what would you consider to be success in your career? Like it must be… 'cause it must change the way you look at the world when you're

always surrounded by these people at the very very top?

HK: That's exactly… true. [laughs] So… what I consider success not that. And I kind of fight everyday to avoid it becoming that. So what I consider success in mathematics is to have a career that like I enjoy and provides a lot of satisfaction and that I'm achieving well at, you know, well considered and have a good reputation, I guess.

BH: Hmm.

HK: As a serious person in it, but I don't want to make the life decisions I would have to make to achieve the… if it were even possible, I mean I'm not trying to be arrogant here.

BH: Yeah.

HK: To achieve the big prizes or the big open questions. I mean really those things are about like significant time commitment and choosing work over other things. And choosing where you wanna direct your attention and time and I don't wanna do that but at the same time, you're right, when you're surrounded by people … or not completely surrounded but many people here do that and then of course they get fancy prizes and big grants and you think, like, oh maybe it would be like really cool to get this. But I know that in the end like the thing that is more important to me is my personal satisfaction.

BH: But I imagine work-wise… I dunno, I'm presuming this maybe it's not true. I would imagine work-wise the biggest thrill you get is like… a new finding and a really good paper being published and like a breakthrough.

HK: Yeah, that's true.

BH: So the… you know but you don't want the steroids version of that?

HK: [laughs]

BH: The Riemann Hypothesis, Fermat's Last Theorem version of that? You're happy with the other version, the kind of just the solid medium breakthroughs? [chuckles]

HK: Well putting it that way now I'm feeling a little like…

BH: [laughs]

HK: …uncertain about my choices.

BH: I don't know what's on this shelf.

HK: No…

BH: The big one could be right here next to me.

HK: [laughs]

BH: Yeah.

HK: Of course I do choose problems that I think are interesting and serious and that other people will care about so there is some thought, there is some strategy in that direction of like, I don't wanna just do mathematics that is medium. What did you call it? [laughs]

BH: Yeah, medium, I think I said medium, yeah.

HK: I wanna do mathematics that is important to the field and useful.

BH: Yeah.

HK: But… that has… that influences more how I choose the problems that I work on.

BH: Hmm.

HK: And less how I choose how to spend my time. So I have like sort of an amount of time that I want to spend on work [laughs] and then that's it. And so I achieve what I can within those limits and… try to be satisfied.

BH: So you do switch off? You're not that person that sits in bed all night not being able to sleep because they're thinking about the problem they were doing that day?

HK: Umm… almost never. [laughs]

BH: Almost never. [chuckles] Sometimes.

HK: Almost never.

BH: What about teaching? How important is… teach… I mean obviously you can't say there and say I don't care about teaching but like…

HK: [laughs]

BH: …most mathematicians I speak to seem to treasure their research time more than their teaching time.

HK: Mhm.

BH: How do you feel about the teaching side of your job?

HK: I definitely empathize with like the treasuring the research time thing because when you're wrapped up in a problem it is so hard to step away from it. [chuckles] and frustrating and you know you feel like it's just there and… yeah. But… I do really like… I mean teaching is the only way in which I feel like I'm actually contributing to society. [laughs] Right, like I'm not a medical researcher. I'm not… researching cancer cures… I'm not… it's not so obvious why anyone cares about what happens to the Mandelbrot Set, right? Like… and so it's one of the few things that I get a lot of personal satisfaction in my job from like actually having a positive influence on other people. So I like that aspect of it, the other thing I like about it is like the performance aspect… which is definitely not universal among mathematicians but like… constructing a good lecture I find to be like a satisfying experience.

BH: So how do you feel when you're lecturing? Is that like that's quite a thrill is it? You feel like you're… like performing for an audience or…?

HK: To an extent. I… thrill is probably not quite the… [laughs]

BH: Yeah.

HK: But yeah, no, I do feel like it's a performance in some ways.

BH: Speaking of performance… you do like public lectures and things like that…

HK: Yeah.

BH: You do Numberphile videos, of course.

HK: I do.

BH: How have you found that aspect of your job like… why do you do that?

HK: It has been a surprising pleasure, actually. I didn't think that I would like to do it. But then I started doing it and I don't think that it's understandable. When you work in a field you don't understand how valuable it is to people outside of that field for your to share your expertise, right? Like I would kill for the chance to spend an afternoon, let's go back to astronauts, I would kill [chuckles] for the chance to spend an afternoon with an astronaut and have them tell me about how everything works and like what the interesting parts of their job are and like all the little details and the fun stories. I would love that. But of course as a mathematician I think like, why would anybody wanna hear that stuff from a mathematician. Nobody cares. And what I've found is that like I am so wrong. [chuckles] And people do care and people do want the expertise shared and so… now that I have some feeling that that might be true, I mean I still find it kind of hard to believe sometimes. [laughs] But now that I know that it seems to be true I actually find it very fun. I mean that's just the main thing is that it's just fun to talk to people who are learning new things from you, and… so that aspect of it I've been like really pleasantly surprised by.

BH: Does that mean you read Youtube comments or…?

HK: I try not to read Youtube comments. [laughs]

BH: Yeah?

HK: The more important thing is I always tell my family members not to read Youtube comments. [laughs]

BH: [laughs] No! Do they read? What do they do? Do they email you and say…?

HK: They did on the first video. And then they promptly stopped. [laughs]

BH: [laughs]

HK: So they learned… you know it's like the hot stove lesson, they learned pretty quickly. [laughs]

BH: Okay. Cool. Very nice.

HK: How do you find hanging out with mathematicians all the time?

BH: I like it. I like it.

HK: Yeah?

BH: But that's because I find… I find mathematics really interesting like… I get… I like… I dunno there's something magical about like just the things we were talking about today in the video. There's something magical about all these… I don't know what it is like it like I get chills sometimes when I see something that should just be like… you know… when you say look at this property and then you'll like pull a rabbit out of the hat and say but then when you get to nine, this happens.

HK: [laughs]

BH: Or it doesn't work for ten.

HK: [laughs]

BH: And [chuckles] why does it not work for ten? And that like freaks me out.

HK: [laughs]

BH: I'm like, oh that's amazing! I feel like it's like… I feel like it comes from somewhere else, mathematics. So I feel like…

HK: Hmm. Yeah, yeah.

BH: I feel like, unlike psychology being made up…

HK: [laughs]

BH: I feel like this is come from another… it's come from you know something… it's like the language of the universe isn't it?

HK: Like that it's really out there.

BH: Yeah.

HK: Yeah.

BH: Yeah.

HK: And it's more, it feels like discovery.

BH: Yeah.

HK: Yeah. I totally agree… it feels like that to me too. I mean people argue about whether it is or not.

BH: Yeah.

HK: But that is certainly what it feels like and yeah it's really satisfying to… to learn about these things. Or it's surprising… right… to look at these surprises and to say like can I figure out like what the universe is actually like constructed

from? [laughs] Like that's kind of the way I feel about the whole numbers. [laughs]

BH: Why do you think that it's important that… we spend all this money doing it? You know why is it important that mathematics is done? I'm happy for you like…

HK: [laughs]

BH: Lucky you! You get to do it everyday, like I'm really envious but why should… why should all the people who may or may not be funding it indirectly or, you know, why do you think it's important to have mathematicians spending an entire career trying to learn new things about the Mandelbrot Set?

HK: So in terms of things that like don't have an obvious application like the Mandelbrot Set for example.

BH: Hmm.

HK: I think there's two ways to look at it. I mean one is that just the basics of like enriching the human experience [chuckles], right? Like why do people paint, why do people write novels?

BH: Yeah.

HK: That I view as like the same thing.

BH: But I feel like to take the other… crazy me taking the other side…

HK: [laughs]

BH: 'Cause you know where I stand on this, but to take the other side for a

moment. Anyone can look at a painting. They may or may not like it, but anyone can look at a painting. Anyone can read a book.

HK: Mhm.

BH: And things like that. Anyone can watch a movie. But like… you're doing things, most of the things you do professionally, all the people who are alive will never understand it in their lifetime. They can't be enriched by what you're doing.

HK: But I think that that is true actually with paintings and novels and stuff like that, right? Like when I go look at, you know, I dunno… Warhol Campbell Cans… do I really… gain anything from it? I don't understand the context, I don't… have any knowledge of why it's a significant piece of work. I don't have any aesthetic appreciation of it. And so I would actually argue that it's the same for other forms of… of art. I think, you know, I'm being a little dodgy. I think you can actually make the argument that it's harder. Right, like there… like I can at least literally look at [laughs] a painting, right?

BH: Yeah. Yeah.

HK: But… on the other hand I think that what you're describing is more of a factor of the way that our society works and not like an intrinsic thing about mathematics. I think that people can understand like some of the basic beautiful things about mathematics, I mean, which is something that you are obviously [laughs] pretty well invested in.

BH: Yeah.

[gentle piano music]

BH: How did you find the cultural change coming from the United States to

the UK? But… I'm not talking about like… in normal society, like, you know, the different biscuits you have to eat.

HK: [laughs]

BH: But mathematically and like academically, what was the culture change like?

HK: So it was not very significant. I would say because like it's a big international group of people in most maths departments. The only thing that I notice is that… I do sort of stand out with my Americanness. [laughs]

BH: Right?

HK: In terms of… the way that I interact with my colleagues is like a lot more… let me think about what I wanna say here. [laughs]

BH: [laughs] American.

HK: A lot more American, yeah, exactly.

BH: [laughs]

HK: No… it wasn't a significant thing but definitely I do detect sometimes that people find me quite abrasive or… a little too… emotional or expressive or some… I'm not quite sure what the right way to say it is but like the cultural difference just in the way that we communicate like in everyday things.

BH: Outgoing and…

HK: Also… [laughs] well, yeah. [laughs] Also sort of changes going from the US to the UK.

BH: Right.

HK: Like for example I was talking to some colleague of mine and like… in the US in school you give like an infinite number of presentations. Like you research some little thing… you know, you learn about a country and everyone gives their presentation on the country or something like that. You do a lot of public speaking as a kid in the US.

BH: Yeah.

HK: And I have been told at least, I don't know if it's true, that that's not so much the experience here. And so it's true that I wouldn't say more outgoing necessarily but much more comfortable in… like that type of position is something that I noticed. But… but other than that I have to say I really… it's not a significant change because of sort of the university culture dominating [laughs] both American and English culture.

BH: And what's next? what's the next big thing? What's the next big thing you're doing? In two years if we do another podcast what… what will be different?

HK: I don't know I mean… I will presumably still be here. Will presumably still do this podcast in this office. [laughs]

BH: Good, yeah.

[gentle music fades in]

HK: As far as mathematics like what's gonna be the big new progress in mathematics? [music fades up] I have no idea. And I'm kind of happy that I don't, actually, I think that… [music continues]… yeah learning about what my

colleagues have done is one of my favorite pieces of the job.

[gentle piano music continues]

BH: Our thanks to Holly for joining us on today's podcast. I'll include some links to her work and her videos in all the usual places. [music continues] Also thank you to the Mathematical Sciences Research Institute for supporting this podcast and to the Berkeley based Meyer Sound for supporting this episode. I'm Brady Haran, and I'll be back with more podcast episodes very soon. [music continues] In the meantime don't forget to check out our videos, we've been uploading a lotta good ones lately, covering all sorts of topics, including prime numbers and Thanksgiving turkeys. [music continues] Catch you next time.

[music fades up and out]