Numberphile Podcast Transcript
Episode: Coffin Problems - with Edward Frenkel
Episode Released December 3 2019

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Edward Frenkel's fascinating mathematical journey - from the Soviet Union to the United States.

Edward's website

Love and Math - Edward's book via Amazon

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Coffin Problems paper (aka Jewish Problems)

Rites of Love and Math - the film

About the film and its Formula of Love

Frenkel research papers

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[gentle piano music]

Brady Haran [BH]: Today's guest is the mathematician Edward Frenkel. His story takes him from climbing fences and sneaking into math lectures at a Moscow University all the way to the hallowed blackboards of Berkeley. [music

continues] It's the sort of story that one might write a book about, [chuckles] in fact Edward has written a book about it and today he's sharing the journey with us. [music fades out]

BH: Where were you born in the world? Not America I'm guessing from your accent.

Edward Frenkel [EF]: [laughs] Yes, you guessing right. I was born in Russian, Soviet Union at the time.

BH: Soviet Union at the time, whereabouts? Is it a place I will have heard of?

EF: A little town called Kolomna.

BH: Kolomna.

EF: Kolomna.

BH: Where is that?

EF: Near Moscow.

BH: Like how far out, like you know?

EF: Umm… hundred and seventeen kilometers. You can google how many miles that is. [chuckles]

BH: Okay.

EF: I guess about seventy miles. One of the good things about growing up in the Soviet Union was that science was highly respected and in particular you could find books, popular books about science in the book stores and so that was

something that really excited me as a kid, as a teenager. I was reading mostly about physics, I was really excited about quantum physics. Things like elementary particles, and forces of nature and the universe. And there were lots of books, some of them were translations but some of them were local, by Russian Soviet authors and they were quite good.

BH: What was it about the culture of the country at the time that would have made science like so revered?

EF: Well two reasons. First of all the nuclear bomb and the research related to that as well as space exploration. The Soviet government knew that they needed scientists, good scientists, good level scientists. And so therefore there were opportunities in that area. And second everything else was controlled by the ideology and so for instance if you wanted to go into social sciences or humanities, you kind of knew you would have to be constantly giving praise to the Communist Party and the great leaders and so on, and so it would be very difficult and everything would be censored, everybody would be looking over your shoulder all the time. So in those ares you could not possibly have the kind of freedom that you could have in mathematics or theoretical science. Experimental science, yes, for instance genetics was ostracized and people were jailed and so on because it kind of was connected to agriculture and stuff like that. So that's where politicians thought they had some sort of authority. Stalin actually went as far as writing a book about linguistics [laughs] as a result of which people… a number of people were jailed and so on, you know, so a lot of people suffered. But even he never made any pronouncements about mathematics. He knew not to cross that line [laughs] so it was lucky for mathematicians. So in other words mathematicians were given relative freedom within their profession. Of course as soon as anybody dared to say anything political they would be you know persecuted and so on. Like Sakharov is a famous example of a physicist who was one of the leaders of the nuclear project and yet he was exiled. So he almost untouchable but was exiled actually.

BH: And are you saying as a boy like as a young boy where you're not totally as engaged with that side of things that…

EF: Yeah so I didn't know all that of course at the time.

BH: Yeah. But are you saying that even at that time the authorities encourage like you know lots of books and stuff about science because they wanted to recruit?

EF: Going to recruit kids…

BH: Yeah.

EF: Talented kids to go into physics and so on and math because they knew it was important for the industry and for the weapons for defense.

BH: Yeah. But that at least is they're showing some foresight and…

EF: Yes! Yes!

BH: Not just thinking about the now.

EF: So that was actually one of the good things in some sense and kind of a respect. There was this sort of attitude where not that they were revered scientists, but they were respected. And their were movies about scientists as romanticized. They were more romanticized as people who are spending, you know, at night in front of blackboard arguing, smoking, you know this kind of stuff. There were movies like that. And that part must have influenced me a little bit but really excited me was the subject itself.

BH: Yeah.

EF: I was just drawn to this hidden reality. To this magical world of fundamental structures of the universe. What is this all about? What's going on? What's really going on beneath the surface? You know?

BH: Were you really good at it? Like were you top of the class? Were you like the…

EF: Yes.

BH: Right.

EF: I was a kind of straight A student you know so school came easy to me.

BH: Was it mathematics that was your number one or were you also interested in literature or physics or chemistry or was it always gonna be math?

EF: Interesting enough, so I was interested in literature and art and so on, but actually math was my least favorite. I hated math, I hated well… that's maybe too strong a word. I did not like what they were teaching us at school. It came easy to me I could solve all the problems…

BH: Yeah

EF: But I was under the impression that what school mathematics was, you know what was presented to us in our classes was exactly what real mathematics was. Maybe problems would become a little bit more involved and so on. Basically along the lines of you know Euclidian Geometry and some equations, quadratic equations and so on and you know. Some kind of simple manipulations with functions, and derivatives and integrals. And I just thought it was trivial and kind of pointless, and boring and stale. And irrelevant.

BH: But easy?

EF: But easy, yes.

EF: So physics was my subject. That was the most exciting subject. Because there were all these crazy particles like quarks [laughs] you know. And this… And also I was reading about people who were making those discoveries. For instance one of them, my heroes, was Lev Landau, so who was actually a Nobel Prize winning Soviet physicist who worked in quantum physics and made some important discoveries. He was a student of Niels Bohr who was one of the fathers of quantum mechanics. And he was a very interesting guy so there were books written about his life, by that time he was dead, but there were fascinating books written about him so I had all his biographies on my book shelf, so I had little photographs, so I took a picture with my little camera, took a picture of a cover of one of the books and then I printed that picture. And I had this little photo on my desk.

BH: So instead of like a famous footballer or a Hollywood star you had this?

EF: I had this guy. So so actually I had this guy. I had Niels Bohr, and I had Albert Einstein.

BH: Right.

EF: Albert Einstein perhaps a little bit more cliche but Bohr and Landau were my heroes as well. And I thought their stories were fascinating how these people were making these discoveries which were just astonishing and went so against common sense I would say. You know, the kind of phenomena of quantum physics are really so surprising. When you first look at them.

BH: You're a school boy. Your heroes are these physicists. You're very exited about physics and this mysterious world of particles and quantum mechanics. Mathematics at this point seems like a bit mundane.

EF: Boring. Boring.

BH: Yeah. What happens that switches? 'Cause obviously you're sitting in front of me as mathematician.

EF: Yes. Yes.

BH: What switched? Why did you change streams? What happened?

EF: There was… something happened… there was an event. There was a singular event, which is very interesting to me as a kind of a metaphor for a lot of things. How much we depend in our lives on our teachers and our mentors or people we encounter which it may appear at first class that it's kind of a chance encounter. But how consequential may turn out to be. I'd just turned fifteen, and I am in just about enter last year of my high school and my mother meets this guy on a bus or something or on a tram whom she had known for many years but had not seen in a long time. And he is a mathematician, so I lived in this town, this little town, population hundred fifty thousand, it was not particularly exited in terms of science education but there was one little college which prepared teachers. So it was called Pedagogical College, so pedagogy. So they were teaching students who would then go on and become school teachers.

BH: Teaching the teachers.

EF: Teaching the teachers. And this guy was a professor of mathematics at this college and he had a name which you know could come from directly Tolstoy's novel, Evgeny Evgenievich. [laughs]

BH: [laughs]

EF: It was a patronymic first name patronymic Evgeny Evgenievich Petrov. So

he was actually remarkable man. So in fact he was sort of out of place there because he's this brilliant guy. What is he doing there? Of course there was also back story for that, as I found out much later, that there was this famous mathematician Rokhlin, a topologist, who was basically unfairly treated by Stalin regime and he was exiled to Siberia and was almost killed, executed but because his friends pleaded to release him. So he was not allowed to go to Moscow or St. Petersburg, but he was allowed to live in my hometown, Kolomna, where he stayed for a few years as a professor at this institute. It was during that time that my teacher was a student in that college. So you see this kind of…

BH: Okay.

EF: This lineage. This lineage.

BH: He'd identified and trained up this promising student that he had…

EF: Who most likely would have been lost, you know, and would not have been able to express themselves fully or achieve their greatness.

BH: okay.

EF: There were a number of people. There were several others who were from that period and they stayed on and became professor of that university. Of that little college.

BH: So this one guy who'd been exiled became this kind of seed of mathematical greatness?

EF: In my hometown!

BH: In this teaching college.

EF: And it could have been any other town, right? So it was literally a provincial place in the middle of nowhere.

BH: So how as it… I didn't ask what your parents did? So how was it that your mother came to become friends with this accomplished mathematician?

EF: Ah. So my parents were engineers.

BH: Right.

EF: But of course so there are more layers to this story because my father wanted to become a physicist, quantum physicist and he was denied entrance to university because his father was arrested and put in gulag by Stalin. So in 1954. And so my father actually finished high school with honors, and at the time he was supposed to be admitted automatically to university and he wanted to become a physicist. But because he was the son of the enemy of the people…

BH: It's like a black mark on his record sort of thing?

EF: Yes. So he was not admitted.

BH: Was that… well I'm sure we'll come to this but the thing that comes into my head, does that black mark go down two generations, is that gonna affect you later on? But I'm sure we'll get to it.

EF: Guess what! [laughs]

BH: [laughs] We'll get to that.

EF: These kind of things have a tendency to repeat themselves.

BH: Okay. We'll get to that.

EF: So that was important somehow for me, I think, unconsciously at least, so now I kind of see it more clearly that in many ways I was fulfilling my father dreams. So we talked about earlier about my interests in physics. And of course it I knew that part of the story that he wanted to do physics but he was unable to so he basically had to go to this engineering college and the he kind of gave up. He kind of didn't really try to pursue that dream, that he had.

BH: Becoming an engineer seems like quite a prestigious…

EF: Yeah, I'm not too disparage in any way the profession of an engineer.

BH: Yeah. What kind of engineers were you parents doing? What kind of engineering were they doing?

EF: Oh my father was an electrical engineer. He was basically sent to this, you know, provincial town and he thought he would just go there for two years and then try and find a job in Moscow and like in a big city. And that's when he came and he met my mother. So you know [laughs]

BH: Change of plans.

EF: Change of plans. And yeah no it's fascinating to see all these twists and turns.

BH: So your mother is friends with this mathematician somehow?

EF: Yes. But my mother knew him because she played volleyball, and this guy played volleyball, so they used to play volleyball together. [laughs]

BH: Okay [laughs] So your mum bumps into this guy on a bus or something like that. Okay.

EF: Oh and she's oh how are you? And they start talking and of course immediately my mother starts telling him about me. Because that's what she would talk to anybody about. [laughs] Most of the time.

BH: Proud of her son.

EF: She was proud of me.

BH: Were you the only child?

EF: No, I also had an older sister.

BH: Okay.

EF: But she was already an adult and so on and so I was still in high school, so it was kind of exciting.

BH: So she was probably saying my son's really talented?

EF: Yes, and this guy's eyes light up. Because he's in this college where frankly there were not probably not so many bright brilliant students. So he's on the look out that he can talk to. And he says oh I want to meet him. And my mother says, sure but I have to warn you he hate mathematics. [laughs]

BH: Okay okay.

EF: You see?

BH: Okay.

EF: And so then she comes homes there this guy Evgeny Evgenievich who

wants to meet you. He's a professor of mathematics in this college. And by the way this college was literally five minutes walk from my house. And so but I was this kind of pouting teenager, you know, so I was just like math… I hate… don't you know that I hate math? [laughs]

BH: [laughs]

EF: I didn't want to go.

BH: No. [laughs]

EF: But she convinced me it was sort of like… it would not be nice. She made an appointment I have to go to this once and talk to this guy and then afterwards whatever. You know if I don't like I don't have to go again. So I said okay fine. And that was the fateful encounter.

BH: That meeting did it?

EF: That meeting kind of changed my life.

BH: What did he do? What did he show you?

EF: What did he do… he's a very clever guy. So I come to his office and he has these lots of books on the shelves, so right? Ah but he already knew my mother told him oh he doesn't like math. And he says well here what does he like? Physics. Theoretical Physics. Elementary Particles. So Evgeny Evgenievich had advanced information and he used it wisely so when I came he asked me so what… I hear you're interested in quantum physics so what do you know about it? And I said well I've just been reading this book about quarks, I said elementary particles which physicists theorized were constituents of particles which previously were thought to be indivisible. Protons, neutrons, et cetera and yet turned out to contain these little smaller pieces. And I was very excited. And

he said oh okay, cool. And do you know about the representation theory of SU3? And I'm like, what SU what? And he says… you don't know SU3, then how could you possible understand quarks? And it hit a nerve in the following sense that I was frustrated by the fact in those popular books that I was reading there was this represented this nice narrative. Nice captivating story, but they never explained the details. Like how did physicist actually come up with these ideas, you know? It sounded mysterious and I was longing for an explanation. So then Evgeny Evgenievich at this point he pulls out this thick book from the shelf and he opens somewhere in the middle. And I could see the diagrams some of which would be in the popular books but they wouldn't explain what they were. But here in this book it was clear that this diagrams were part of a theory, of an explanation, an actual explanation with formulas and equations. Which I couldn't make heads or tails of at the time. Right? And then Evgeny Evgenievich pointed to those pictures and formulas and said, you think what they teach at school is real math? No. This is real math.

BH: Right.

EF: [gasps] [laughs] I was like yeah I might have as well been struck by lightning. It was just one of those moments was like my god there is this thing which I had no idea, you know, that exists and obviously holds the answers to all those questions that I wanted to find.

BH: But what happens now because like teenage you now just has to go back to high school where your just being taught the basic mathematics and you're not getting access to all that stuff. So how do you get access to this thing that you've just seen.

EF: So exactly so I was like how do I learn all this? It looks complicated. And he says oh its okay, I can teach you, I can see you're a bright kid, so if you want you can come and talk to me every week and we'll figure it out. I will explain to you. [gasps] Wow that was so exciting.

BH: So he became like a private tutor?

EF: Yes. Once a week I would go in like in the evening and sometimes we would just stay late til like nine or ten, once we were locked in the auditorium by a custodian who didn't even bother to check were there was anybody in the room. Luckily it was on the ground floor so we could get out through the window but it was very funny. And so he gave me books… he said we can't jump immediately into this stuff. You have to first learn the basics. So he gave me a few books… there was a book about linear algebra for example. So that he said linear algebra is the basis of mathematics. Interesting enough I'm teaching a big class at Berkeley of linear algebra which I have taught many times. But this was… yes you have to learn this, this is absolutely fundamental. And then there was a book about number theory, there was a book about topology which is a branch of geometry. Which probably your listeners know about. You've must have done a bunch of videos on Numberphile. And then I would read those books, I would come, and he says okay what did you read and tell me what you read, do you have any questions and we would discuss, and some nights I wouldn't sleep. I would have sleepless nights just thinking about this stuff. It's like wow, you know, it was just like a new world.

BH: Yeah.

EF: And in a way it was an escape, also. It gave me this escape from… because you know the Soviet Union was starting to deteriorate. We're talking about the early mid Eighties. So we're talking about just before Perestroika started and the soviet union collapsed and so it was kind of like depressing in many ways to be. To live in the country at the time. But then were was this magical beautiful world and I didn't have to go anywhere to find it. It was right at my finger tips, you know, it was just really marvelous.

BH: How was this like advanced inspiring education you were getting once a

week meshing with still having to sit through boring math lessons at school?

EF: Well I had a newly found appreciation for this stuff. Because now I could see that through the lens of this sort of higher math that I was learning and that actually made a lot more sense I could see that it wasn't boring, it was just that it was kind of elementary and the teachers themselves they were not… they did not know how to explain the kind of… they were not properly educated themselves to make the connection to some other things which would pique the interest of the students, you see. But the subject themselves were fascinating actually if one could see them from a slightly higher vantage point.

BH: At what point does this like new appreciation of mathematics… because I can imagine this new appreciation of mathematics is also enhancing your enjoyment of physics?

EF: Yes.

BH: Because it's helping you under the physics more deeply. At what point does kind of mathematics overtake physics and you start thinking I don't even wanna do physics, I almost wanna be a pure mathematician now?

EF: Very quickly. I mean and he was clever because he wasn't putting as a question of substituting one subject with another. He said, if you want to understand theoretical physics, especially quantum physics, you have to have a good understanding of math, because it's all based on math. So before that you could not really do physics. He said all these physicists who theorized all these beautiful theories that you heard about or read about, they did that based on sophisticated mathematics. And it was very convincing 'cause he showed me those books and I read so, so I was like okay, then I have to do the math. But very quickly I discovered that the math that he was talking about was actually very interesting in its own right. So I became very curious about that even not necessarily because of its connection to the original… my original interests but

just because they were so exciting things but they were hidden from me until that point. They were kind of veiled and then suddenly the veil was lifted and it was like okay look at this, there's this. And I was like okay this is great, so my hands were full [laughs] with just with that stuff.

BH: Do you remember a branch of mathematics or a theorem or a field that you were taught about at this time that's a really exemplar of oh my goodness where did this come from?

EF: Yes. So there was this one thing which I found absolutely incredible. And that's called P-adic numbers so it's a P and there is a little hyphen and then adic. A D I C. P-adic numbers. So it turns out in addition to the numerical system that we are used to such as well actually let's just say real numbers. So real numbers. So meaning real lines, they're called the points on the real line. Including zero, one half, pi, you know, e, the square root of two, golden ratio, and so on, right. So real numbers? It includes all rational numbers which are ratios of whole numbers, whole numbers themselves, but it turns out that there is sort of a parallel world to the world of real numbers. And that's the world of P-adic numbers, so P here is a prime number. So it could be two, three, five, seven, eleven, etcetera. Let's fix a prime number, let's say five. Then there exists this five-adic numbers. There is this collection of numbers, it includes rational numbers, just like real numbers include rational numbers. But they have totally different properties. So what do I mean by numbers? They form these numbers, P-adic numbers, they are elements of this set which have fundamental properties very similar to the properties of real numbers. You can add them together, you can multiply them, there is a zero element, there is an element one, there is negative of every element. And then there is a multiplicative inverse for every non-zero element. So it's what mathematicians call a field. And it contains rational numbers. And in a certain sense it is a completion of rational numbers, the way real numbers is a completion of rational numbers. But it has totally different properties. So for instance whereas a real number you can write in decimal form, where each digit after the decimal point represents a piece which

is smaller and smaller. So for instance if you have something point one, it means like one over ten. And this point zero one is one over hundred. Right?

BH: Yeah.

EF: So and so on, it becomes exceedingly smaller. But the P-adic numbers, a five-adic number say so let's say that P is five. P which has to be a prime we can choose P to be five which is a prime, then we have this five-adic numbers. And the five-adic numbers each next number is bigger. So point one would be five. Point zero one would be twenty-five. So the convergence property is exactly opposite. It's like you reverse. You have binocular but you reverse the binocular. So the notion of distance for these numbers is reversed from the notion of… it's kind of reversed from the notion of distance for real numbers.

BH: How have we not a Numberphile video about this yet?

EF: I don't know, okay. [laughs]

BH: [laughs] That could be next on our list.

EF: Alright.

BH: So that was an example of something that… yeah…

EF: So that I actually remember how when I first read about it and I tried to understand what these numbers look like. It looked so counter-intuitive and I was reading… so this was I read a very nice book about them. Which my teacher, my new teacher, my mentor, Evgeny Evgenievich gave me. And I remember this I could not sleep all night long just think about it. How is it possible that this thing converges even though it doesn't converge?

BH: Yeah.

EF: [laughs] You see?

BH: Yeah so.

EF: So that was one thing which really stood out. That's one concept and it kind of helped me to see this hidden side of mathematics. When I say hidden I mean from the point of view of a student who just goes to regular classes in high school or whatever.

BH: Hmm.

EF: Where normally they didn't talk about this stuff. This sort of really ideas, kind of like outrageous ideas. Like really crazy, like wow exciting ideas which are very counter-intuitive. Captivating things. This was to me like an epitome of that.

BH: Take me to the end of school then. Like what happens as you come to the end of high school? You're still getting obviously excellent marks at school and…

EF: Yes. Yes. And I'm super exciting about all this stuff and every Monday whatever it was I don't remember which day of the week. I would go meet with Evgeny Evgenievich and so then it becomes clear so this my last year of high school it becomes clear that I want to be a mathematician.

BH: A lot of people who I've spoken to who are mathematicians now when I speak to them, they always say to me when I was in high school I didn't even know what a mathematician was, I didn't know it was a job. But it sounds like because of your exposure to Evgeny, you did know what a mathematician was. Right?

EF: Right. And he was, you know he was actually looked like a

mathematician too in some sense.

BH: yeah. [chuckles]

EF: So he had these thick glasses. [laughs] I was wearing glasses at the time too by the way.

BH: Okay. [laughs]

EF: I was a totally nerdy kid [laughs].

BH: Yeah. Yeah.

EF: And he was wearing glasses and he was just a chainsmoker also. [laughs] Not necessarily a good thing.

BH: No. [chuckles]

EF: But and he was just sort this guy very smart, you know, and he had this stubble of a beard you know…

BH: Did you want to be like him? like was…

EF: So in some ways I guess I wanted to be like him, yes. Yes.

BH: Yeah. yeah.

EF: So he fit the profile. [laughs]

BH: Okay, so you were at the end of high school, I wanna be a mathematician, what do you do next? How does this happen?

EF: So I talk to him about it and he says look, there is basically only one place in Moscow. First of all I would have to go to Moscow, obviously not applying to this little school, you know, this little college. There was not much opportunity after that, getting a diploma. Even though remarkably it had a professor like that, you know, so it wouldn't be such a bad thing necessarily but yeah I was shooting sort of for the stars. Okay I wanna go to Moscow, which was not that far away. And Moscow had the best schools in the Soviet Union, also St. Petersburg which was much farther away.

BH: Yeah.

EF: Okay so the only school, only place where you could study pure mathematics. Not applied mathematics in other words mathematics in connection to some real world problems. Specific problems, but pure mathematics just for the sake of it so to speak, which is what I had been studying for a year by then. That place was Moscow State University. And was just this grand building you know like, sixty or seventy story building, beautiful in Moscow which I had seen on postcards and I had seen it when I came to Moscow so it was clear that I have to apply to that. It was the department of mathematics and mechanics and that's where all the best mathematicians of the Soviet Union worked.

BH: Okay so you've applied…

EF: And I applied. Yes. And interesting enough the year was 1984, I'm not making this up [laughs]

BH: [laughs]

EF: So the readers of George Orwell will see the parallel. This is the last year before Perestroika. So Gorbachov comes to power in 1985 and the Soviet Union starts changing. First slowly then faster and faster and then to the point in '91 it

disintegrates and collapses, right?

BH: Yeah.

EF: But this is 1984 and exactly the quiet before the storm. So the total stagnation, the total everything is controlled by the party Apparatchiks, and ideology and so on. And one of the consequences of that, unbeknownst to me, because you know I was sixteen years old, I'm sixteen years old at the time?

BH: Yeah.

EF: When I present myself to the exams, entrance exams, unbeknownst to me in Moscow University they had this sort of cabal of anti-semites, these professors who kind of completely controlled the admission process. And this happened… there actually there is a bunch of articles about this that had been published in recent years. Apparently it all started in the Seventies. So by then they were deeply entrenched for about ten years, these people. And they completely controlled the admission process. And they had a very sophisticated in place to fail students who had anything to do with Jewish nationality. Not religion mind you, so it's very interesting. Because in the United States or in Europe people say Jewish it usually means in a religious sense.

BH: Yes.

EF: But we're talking about the Soviet Union where religion was all but nonexistent. My father was Jewish by blood, not by religion, so he was not… he was an atheist actually. And his parents were not religious either. And my mother was Russian and the only religious person in my family was my maternal grandmother and she was an Orthodox Christian. So she actually went to church and she would cross me before my exams. [laughs] You know so that was the only exposure to religion. But the authorities tracked nationality, they call it nationality, so it means by blood. So for instance everybody had a passport,

internal passport, where they would put your first name, patronymic name, last name, date of birth and then number five, the fifth line would be nationality. And so in my case the nationality was written as Russian. One parents was Russian, was deemed to be Russian, the other parent was deemed to be Jewish. So I could choose. But my last name clearly sounded Jewish. [laughs]

BH: Right.

EF: And in fact my father in his passport had Jewish as nationality.

BH: I know you weren't aware of this discrimination that was happening, but were you very aware of your Jewishness? Like would you have known oh yeah my dad has Jewish in his passport and…

EF: That's a very good question, so I was… when I first found out I was shocked.

BH: Right?

EF: I was completely…

BH: So it wasn't part of your upbringing? It was just… yeah?

EF: Not at all. My father had no interest somehow in actually in language or culture.

BH: Yeah.

EF: Which is not necessarily a good thing, but in the Soviet Union it was kind of dangerous to venture into those territories. And there was a lot of unfortunately anti-semitism at the kind of domestic level. You know kind of like just kind of… I'm sure that some parents would make remarks to their kids, so it

was just sort of in the air. It was sort of in the air. So when I was about eleven or twelve there were a bunch of kids in my school who took on you know bullying me and taunting me, like you're a Jew, you're a Jew. And that's when I found out. [laughs]

BH: Okay so…

EF: According to them I was a Jew, so I didn't know what it meant, but it meant to endure their insults.

BH: Yeah.

EF: Luckily there was one guy, there was one classmate of mine, only one who stood by me.

BH: Right.

EF: And so these people… these kids they would surround me if I were alone they'd probably beat me up, but because there was this friend who would always stand by me, and interestingly enough he came from the poorest family. He was very bright guy but he came from the poorest family. But he had a moral, you know, compass. I would say, many years, you know, I had the opportunity to thank him for this.

BH: Brilliant.

EF: Because I said you know, you really did something important, for me. So he would stand by me so these bullies were not, they were afraid, because I was kind of… I wasn't… yeah I was nerdy kid but I was strong, so I could hit back. You know and then with my friend together we would actually… [laughs]

BH: Okay, you had the firepower [laughs]

EF: …beat them back… but that was the first time I found out that I was Jewish.

BH: Okay.

EF: In that sense, that's being different.

BH: But you didn't think this could potentially hold your career back.

EF: But… I did not, not at all.

BH: Did Evgeny know? Evgeny sounds like he was a man of the world and knew mathematics. Could he not say, hang on you might struggle here to get into the university? Or did he not know that either?

EF: Well because we lived in this provincial town, people didn't really know what was going on in Moscow. In Moscow everybody knew, but we were kind of under the impression we though… why would anybody bother with mathematics because it's nothing to do with Defense for example or anything like this. We were naive kind of, me and my parents we were naive, and we didn't know any stories of people who were denied entrance.

BH: Okay.

EF: But we knew stories of physics departments where Jewish students would be denied entrance.

BH: Oh okay.

EF: And the story was it's because the government is afraid that they would emigrate to Israel with their secrets and take with them the State secrets or

something. You know, But math? Who cares about math secrets?

BH: So what happens when you apply to Moscow then? Do you sit the exam and like do you actually sit exams and...?

EF: There was a written exam, mathematics written exam, then mathematics oral exam and then there were two more, there was literature composition and there was a physics. So written mathematics exam I actually solved… I just went and solved all the problems. Even though everybody said you cannot solve the last problem. It's an unsolvable. But I didn't know I couldn't do it so I did it, you know [laughs]

BH: Okay [laughs] and solved it!

EF: I solved! And so afterwards I came home and Evgeny Evgenievich came to our place and I explained to him all the problems and solutions and said everything's correct. So I was actually happy, what are these people talking about, by that time I kind of got the whiff that this might happen, that they might fail me, I got some idea about that, but I was in denial.

BH: Okay.

EF: I was very upbeat, and kind of like okay they're gonna give me an A and I'm just gonna sail through.

BH: Yeah. You'll be the exception because you're so brilliant.

EF: Exactly! Exactly, how can they fail me? Right? So then there was an oral exam a few days later and that's when crazy stuff started happening.

BH: Oay.

EF: Yeah.

BH: So what they were like saying solve the Riemann hypothesis? [laughs]

EF: [laughs] No! In some ways it was much much worse. First of all you are in this room with like twenty other kids and you have to pick out a ticket so it's like a ticket a little piece of paper, and there're two questions… there is a list of questions which is given in advance, there may be eighty questions, each students gets two, have to answer two, and then there may be follow up questions.

BH: Okay.

EF: So I get my ticket, my two questions, and then I have to sit down and prepare and my ticket, and first of all I knew all of it. Through and through. And those were particularly simple, after two minutes I raised my hands, I'm ready. And there are three examiners in the room and none of them… they all look through me. They don't come to me. So finally I grab one of them by that time in like half an hour or fifteen minutes other kids start you know raising their hands. One of them I just grabbed his by his jacket and I said why are you not talking to me? And he says we are not supposed to talk to you. That's when I… is like the reality hit home. You know it's like, uh oh.

BH: So you eventually did get to do it, did you? The oral exam?

EF: So then a special group…

BH: Ahh…

EF: A special two examiners arrive.

BH: Oh okay.

EF: And they come to the front table in front…

BH: Okay the bad cops

EF: …and they are like [grunts] and they point at finger at me. I was the only one, the ostracized one in this room.

BH: Okay. okay.

EF: And I was like okay my inquisitors have arrived.

BH: Okay.

EF: You know?

BH: The men in black.

EF: The men in… well yeah much worse. It was on the one hand well… when I look back… on the one hand really what a terrible thing to do to a sixteen, seventeen year old…

BH: Hmm.

EF: …child you know, and a lot of my friends who went through this, future friends who I met later, who we shared the same story, so some of them never recovered. So they kind of really suffered from this.

BH: Yeah.

EF: Because the way they… it was approached was the worst possible. If they actually came to us and said, look you are fifty percent Jewish, fifty percent of

you blood comes from Jewish you know family whatever and that's why we cannot accept. So okay, so you are like this is a draconian unfair you know policy.

BH: Mmm.

EF: But it's not because I'm not good enough, it's just because that's how it is, so I will have to deal with it. That's not what they said. Because it would be illegal to say that, because in the Soviet Union of course all nationalities are equal.

BH: Right.

EF: So they had to trick you and give you questions which on the surface looked like normal questions but would ten hundred times harder which they would never give to regular applicant. And then they would pretend those were the real questions that they give to everybody and because you didn't solve them you are actually not good enough.

BH: Hmm.

EF: And that a lot of people including myself were traumatized by at some level. So you know it was really really tough experience. Because my exam was about four hours and I fought with everything I got. You know [laughs]

BH: Yeah

EF: But in my… well I'm not sure how much in my book Love and Math, I actually describe some of the questions that they give me.

BH: Right?

EF: And there is a lot of testimony… there are actually articles been published

with lists of problems. It's actually to see now it's a kind of a historical artifact. To what length these people went to be able to deny something to people that they hated for no reason at all. My examiners had never met me. In fact interesting enough after the exam I happen to be one on one with one of them in the elevator and he was giving me compliments. He said you're so brilliant, you know. So why was he doing that? And to what length to go to do that to somebody you never met, right? To what lengths, how much effort they put to create these problems, meticulously. These problems which look like… they were called Coffin Problems for some reason.

BH: Coffin Problems.

EF: Coffin, yes, coffin. Because they want to put you in a coffin, you know? With this problem. So it is deceivingly simple, you know but then… and you can if you do google Coffin Problems Moscow State University you'll find plenty of them. If any of the listeners are interested they can find essays… nowadays if you don't think too much about the history and what this actually meant to a lot of human beings, real human beings who suffered tremendously from this, but you just look at it as a mathematical problem it's actually really interesting. It's kind of an interesting challenging quest, come up with some problems which look like high school, like regular high school problems and yet… even professors will be stumped by them. You know so really complicated, they're really hard to solve. So that's what happened. So in the end was I was denied… I was failed.

BH: Did you come away from that experience with what you talked about thinking I'm not as good as I thought I was? Or did you know they stitched me up? I am good enough but they stitched me up here. Which of those two were you?

EF: I knew. I knew that they stitched me up. I knew that it was unfair. So…

BH: Okay.

EF: Luckily for me.

BH: Yeah.

EF: Luckily.

BH: It's almost like your ego was intact almost because of that?

EF: No actually, more… it was more than that I was resolved to prove them wrong.

BH: Ahh.

EF: So it gave me that fuel actually. So…

BH: But what can you do? There's only one university to do this?

EF: Yes so… an interesting thing happened at the end of this four hour exam. Is that one of those two inquisitors, one of those two… and they were so nasty you know, they'd be like this is wrong, like what is the definition of a circle? And I'm like a circle is a set of points on a plane equidistant from given point. And he says no! That's wrong! I was like… what? How could this be wrong? It's a set of all points equidistant from a… [laughs]

BH: Right.

EF: Yeah it was like you didn't put the article in the right place.

BH: Okay, yeah.

EF: And they'd be so cheerful about like finding this little nitpicking, you

know?

BH: Yeah.

EF: But suddenly when after the exam I told him I actually want withdraw my application. They were worried because sometimes people would apply and then they would have to clean up the mess sometimes, you know, so that it will then come out easy for them if the person is broken by this process and they just withdraw themselves.

BH: Okay, yeah.

EF: And not appeal. Sometimes people appeal… there was an appeal process.

BH: Okay.

EF: But I decide not to go through thank god because it would be totally futile. And I said you know I want to get out of here and he said… and I said but by that time it's like seven or eight PM and it's like how could I get my application because there's actually stuff like documents which I actually like left in their admission committee. And he said oh it's okay I take you there, I have a key. And so we were in the elevator for a couple of minutes or a minute, just the two of us and that's when he suddenly starts giving me compliments and he says oh you are so brilliant. How come? You know. And I was like… you gotta be kidding me.

BH: Yeah.

EF: But he gave me a good advice, he told there is one school in Moscow which takes students like you…

BH: Okay.

EF: [laughs] You see…

BH: Like you… yeah.

EF: Like you… and it was… and he gave me the name it was a university which was called Oil and Gas University. Which sounds strange, right? Why an aspiring mathematician would want to go to Oil and Gas Institute? But this Oil and Gas Institute had a small applied mathematics program.

BH: Okay.

EF: And so I took him at his word, because I figured why would he be lying at this point?

BH: Yeah.

EF: And I actually applied and indeed they did accept me. And moreover ninety precent of the kids… it was much smaller program, there were like one-tenth of the Moscow University Math Department but ninety percent of my classmates in that school… suffered the same fate that I did.

BH: Right. So they had Jewish parents?

EF: Jewish parents, or they were… some of them, but almost all of them were from Moscow. So they actually went to special schools and stuff and so for them it was even more outrageous. Like I came from this provincial town so in principle you could say you come from this provincial town, your knowledge is just not good enough here in Moscow.

BH: You were sort of almost still ahead of the game because now you're at least at a Moscow University.

EF: Right right, but those kids they shared stories and their… in some sense what happened to them was a lot more outrageous…

BH: Yeah.

EF: Because they were like… like they had classmates like dozens of classmates who were accepted and whose oral exam would be like fifteen minutes and they would be like you know, you're in! And for me it was like hours and for them as well. So anyways, so that was how I got a foothold finally in Moscow. And that university was really nice in many ways… it gave…

BH: Was that an inferior education though? Was it?

EF: No… well it's not inferior. It was just different because… certain level was really high and people, the professors were really great as human beings and as professionals that we didn't have obviously the greatest mathematicians some of who were at this Moscow University. But also the drawback was that because it was geared towards applied area some of the hardcore math courses, pure math courses, were not taught. So I had to learn this on my own basically.

BH: Hmm. Okay so there was again the little bit of self education on the side?

EF: Oh yes, a lot. So here's what… it's interesting that what happened was so first of all I was lucky to be at this school because as I said many of my classmates actually came from the tradition of like really best math education in Moscow. In Moscow there were specialized schools for mathematics. And most of the kids in my class, my classmates you know, at this Oil and Gas University were from those schools. And so they knew… they had many classmates who actually were accepted to Moscow University, so they could find out what's going on, what courses, what seminars and so on.

BH: Oh okay.

EF: And for instance one of the kids who was a classmate of several of my classmates his father was like a great mathematician who was a professor at Moscow University and he was very kind and he always welcomed us at his seminars.

BH: At Moscow State?

EF: At Moscow State. However to get into Moscow State was not easy. Because the building was guarded by the police. [laughs]

BH: [laughs]

EF: You know its funny because I… at some point after my book was published I was interviewed by somebody and I recounted this part of the story and the interview you know she said, hmm interesting she said in this country they tried to keep students inside [laughs] the university.

BH: You're sneaking in!

EF: In Russia they tried to keep… so at uni they tried to keep you outside.

BH: How were you getting in? Were you having to sneak through backdoors or…?

EF: So my classmates they were, you know, clued in. You know, so they knew what was going on so they said there is a way. So you go on the side of the building where there is an entrance for the trucks for the cafeteria…

BH: Ahh.

EF: And there was a gate which was a little bit crooked and so you could kind of climb up almost to the top of the… and it was big it was like a big gate maybe up five, six yards. You climb to the top and then it kind of gives you an opening and you can sneak in.

BH: Sneaky.

EF: And then we would walk into the cafeteria and through the cafeteria with all these cooks looking at us who are these guys?

BH: Yeah. You're like, we're here! Where's the mathematics? [laughs]

EF: [laughs] and run through the cafeteria and come out and then take the elevator to the… it's crazy you know if you think about it. Later on, two or three years later, I was able to get an ID, a pass to be able to walk through the front door. But you could not get through the front door, there was a policeman, there were several policeman there, so they would not allow somebody who is not registered as a student. But we found a way, we'd climb over the fence and go. So I was continuing to meet Evgeny Evgenievich occasionally when I came home, you now, on the weekends…

BH: Yeah.

EF: But basically it was kind of after a year or two of in this school I was kind of running out o steam. And that's when I was… I lucked out again. So there was again a human being, a generous human being who took me under his wing. And he was a great great mathematician. His name is… since we follow the Tolstoy tradition, so his patronymic name Dmitri Borisovich. Dmitri Borisovich Fuchs. And actually interesting enough Fuchs immigrated to the United States about 20 years… no more than maybe… almost thirty years ago and he's a professor at UC Davis. Not so far away from me and he just turned eighty.

BH: Uh huh, right.

EF: On October 1st… on September 30th. And I actually dedicated to him my… one of my recent math papers. So it's kind of an interesting…

BH: How did…

EF: …reminder to me of how much I owe him, you know, and his generosity.

BH: How did you come to cross paths with him?

EF: It was kind of by chance. The whole thing sounds really improbable but there was a person in my school who kind of took a note of me. And then he had a… he was a very good mathematician in his own right and still is. And he had a problem that he had to solve which was in the area of topology which was an area where Fuchs was king. And so in those days it was quite common that these people they all knew each other. So he would ask Fuchs how to solve this problem. And Fuchs said I don't know but it shouldn't be very hard. Normally I would give it to a good graduate student to solve. But since you work at this Oil and Gas Institute with these unfortunate souls who were denied entrance, why don't you find a bright guy in there and give him… him or her my phone number so that I could supervise their little research on this.

BH: Right.

EF: In private.

BH: Okay.

EF: You see?

BH: YEah.

EF: So my professor… so Fuchs could give it to somebody in Moscow University but he was mindful of what's going on and people like him they wanted to help, they wanted to find some little way in which to at this to help somebody to overcome the system, you see? So for me it's always like this story like people say…

BH: Is his thinking… could there be like you know a Ramanujan hidden there in the Oil and Gas or is it like, this is sort of cheap grateful labor or…?

EF: Oh no not cheap or grateful labor… for sure not! No, I think it is really a human being, a decent human being trying to help those who were unfairly treated. Treated unfairly.

BH: Yeah.

EF: You know? And so to me it's like people… you know… I talk to all kinds of people and over here there's like the system is so rotten and so on you know? Yes, it's true, perhaps, you know, but in some sense that's the job the system to be rotten. So the job of the system is to block. That's how… it's kind of an inertia. So of course sometimes it takes grotesque proportions, like denying you know sixteen year olds entrance to university which is absolutely atrocious and terrible. But by and large you have to expect that there will be obstacles. So in my case there were maybe a little bit too much but all of need for obstacles. One way or another. If you try to do something different, if you try to do something sort of even slightly off the beaten path…

BH: Yeah.

EF: sure enough you will meet resistance. So first of all don't be surprised, don't take it personally, and keep going and keep following your heart, keep following what you think is right and at some point somebody will come and

appear and open… so I had to climb over the fence…

BH: Literally…

EF: Literally. And yet because I did not give up for two years, you know, doing this in Moscow. There was this man who appeared and he basically he's like okay, here is a hidden door, I'll let you… I'll take you.

BH: And you impressed him?

EF: And then I impressed him and I very quickly I wrote my first paper, so I was eighteen years old you know, and my career took off. And three years later I was a visiting professor at Harvard.

[gentle violin music]

BH: How did you get from writing your first paper at eighteen to suddenly being at Harvard? That seems like a quantum leap.

EF: But can you imagine! So for me now to speak about that kid you know, that teenager that I was, can you imagine the drive. Can you image how much he wanted to succeed and to prove those people wrong.

BH: Yeah.

EF: You thought I was not good enough… well let me show you. Let me show you. So in that sense when I look back of course that… being failed… having been failed like this brutally you know it was a horrible horrible experience yet at the same time if I was strong enough then it gave me that energy.

BH: Hmm. Hmm.

EF: That energy.

BH: Steel.

EF: Steel. That motivation. To work harder. And that's why you realize that actually these obstacles have these two fold, there are two things. So the essence it may be something very difficult

BH: It would break a lot of people though

EF: It actually could break people too but if you are able to just hold tight and kind of say no I'm going to do, then actually you can turn it around. It's kind of like a Jiu Jitsu kind of move, so suddenly you use that momentum of your opponent to actually propel you to the next height. You use that energy to actually go further that you would… I would never have got… I'm pretty sure I would have never achieved, you know, as much as I did in such a short period of time had I not been subjected to this very unfair treatment. You know where I knew deep that it was wrong. And I have to show… I have to prove. So that was important. Of course then as I said I owe this tremendous gratitude to my teachers. So there's was Fuchs and then there was another fellow, who was his student and his co-author. Boris Feigin who became my teacher… my real like close collaborator and teacher and so by fourth year he and I wrote… Feigin and I wrote a bunch of papers which kind of became well known. So they say. And based on that reputation I receive a letter from the president of Harvard University… barely twenty-one, in last year of college in Moscow. And I receive a letter and the letterhead of President of Harvard University, signed by Derek Bach who was the president of Harvard University at the time, 1989. Saying we would like to invite you as a visiting professor.

BH: Huh. Amazing. So obviously does this mean mathematicians at Harvard had seen your papers and just said, we've gotta get this young guy?

EF: Yes. And there were people who were apparently had high opinion of me who kind of also whispered in the ear of those who made decisions.

BH: Okay.

EF: So there were many angels so to speak. Many guardian angels who helped me so along the way.

BH: This sounds like a stupid question, I'm sorry if it is. Did you speak English at this point?

EF: [laughs] It's funny you would ask.

BH: [chuckles]

EF: I had difficulties, you know. The first time I went to the supermarket in Boston, I couldn't find salt, you know?

BH: Yeah.

EF: And was… I kept… well part of it was that I was overwhelmed by the abundance of food…

BH: [laughs]

EF: Because in the Soviet Union at that time… in 1989… there was nothing on the shelves. Nothing you had to know somebody to buy from the backdoor, you know? From a supermarket. There was no such thing supermarket, actually, they were like small shops. Anyway so I was just… I think I was hypnotized by this. I was just wandering the aisles… [laughs]

BH: [laughs]

EF: It's like what is this?! And I tried to ask people where is salt.

BH: Yeah.

EF: And I couldn't understand what they were saying.

BH: So you could speak like broken English?

EF: I could speak, I could give seminars at Harvard, you know, I could talk my mathematical work and in fact I wrote my paper which brought me to Harvard in English.

BH: Okay.

EF: But my colloquial English [laughs]

BH: Was just not good?

EF: Left something to desire.

BH: [laughs] Okay.

EF: So the way I learned actually… what was helpful apart from looking for salt at… [laughs] Boston supermarket, was watching late night television.

BH: Okay.

EF: David Letterman was… [laughs] king of… well as far as I was concerned anyway was king of late night at the time. And I was watching him religiously.

BH: Okay.

EF: And then videotaping and watching the next day and trying to like… would play the same sentence several times to understand what… what was it that he was saying.

BH: So without being too… without being too technical and if it's possible. What is the area of mathematics at this point that you've made your name in? These papers you wrote that were so groundbreaking and the things that brought you to Harvard? What's this area of mathematics called?

EF: The general area which I mean it's the focus of my research is called the Langlands Program after a mathematician Robert Langlands. He's a Canadian born mathematician and is currently Professor Emeritus at the Institute for Advanced Study in Princeton, where incidentally he occupies the office of Albert Einstein.

BH: Huh. Nice.

EF: So about fifty years ago he came up with these groundbreaking ideas about connecting problems in two different fields of mathematics. Number theory and harmonic analysis. And there were a lot of people got very excited about this and it sort of became this big area of research. But actually what happened next was even more surprising that other mathematicians found very similar patterns, similar things in other areas of math. Including geometry, and then later quantum physics. So in fact… [laughs] you will… those who will listen from the beginning will appreciate this [laughs] my research in the last few years had been on the interface of mathematics and quantum physics.

BH: Ah you got there!

EF: Exactly the kind of stuff I wanted to do, you know?

BH: You got there in the end! [laughs]

EF: [laughs]

BH: Okay, right and…

EF: It's a Hollywood ending, you know. Although it's a continuance in some sense.

BH: Did the move to the United States really boost your ability and your career? I can imagine to some extent it might make you… fat and lazy?

EF: Oh, sure.

BH: You might think I've made it, I don't need to prove anything to anyone anymore. What became your motivation to keep succeeding once you succeeded?

EF: [chuckles] Right. Right. Well, I guess the spring was coiled so tight you know.

BH: Okay.

EF: After that exam that it could last many more years.

BH: That one day… what that one day did for your life.

EF: That one day, oh my god yeah.

BH: The scars of that one day.

EF: It's incredible, yeah. And took so many years for me to actually come to

terms with. Because for many years I was in denial of what happened. So I didn't fully appreciate what a traumatic event actually it had been for me.

BH: Yeah.

EF: So it took a lot of pain and sort of difficulties took actually reconcile myself with that child, that sixteen year old, whom I kind of left on that battle field.

BH: Hmm.

EF: Which is normal. You know that's what we do. But if we are lucky we come back, eventually when we get stronger we come back and so and to bring him back and to be more in touch with that reality and also appreciate that reality also. So it was tough but we made it, you know we did well. You know? And so but why do it? So I guess it's because I'm really interested. I'm really… I think as we reach a certain middle age you know, I'm now fifty-one so I think it's natural to start asking why do it. So I had this period a few years ago when I actually start questioning, do I actually love it or do I do it just by inertia, you know? And there was a lot of sort of contemplation of this, it wasn't clear what the answer. And I knew that I was ready to move on to something else if I don't like it anymore, you know?

BH: What… away from mathematics?

EF: Yeah. I could. I would. It was like why… and this came with these discoveries of my past and like I said early the really understand what happened when I was sixteen and a lot of other things that happened in Soviet Union which some of that was beautiful but some of them less so, you know? So when I felt much more in touch with myself and I was kind of more prepared to be honest with myself with what am I doing? Why am I doing this? And also the fear of… so like I saw how much of my daily life and my research even is driven

by fear. So I want to be relevant for instance. I want to still produce articles that people cite and invite me to conferences and stuff like that. So I'm still relevant, you know? That idea is based on fear. So it's like I'm afraid to be… that you don't remember about me. So who cares? What matters whether you love doing it or not, right? And so… because it's very easy to get… just go by inertia. Write one paper, then write the next one and just go day after day. Writing my book, which was about six years ago it was published was very helpful because it helped me appreciate more what mathematics really is about. The beauty of it. Because I had to… I felt compelled to articulate for others and articulated for myself as well [chuckles].

BH: Yeah.

EF: I remember that night I mentioned earlier, you know, when I couldn't sleep because of these P-adic numbers. I still get goosebumps when I think about it, you know, so there is that thing which is just… I just love it, I am curious about. I want to know, you know. So that's ultimately I think is what motivates us. It's because we're really curious, because it's such a beautiful subject. Unfortunately very few people get to see how beautiful this… unlike art or literature or movies where it's much more readily available. Mathematics is hidden. So but more and more people now doing a good job exposing this beauty to others.

BH: So your book, and I will link to your book in the notes to the podcast, it's sort of your book seems to have two threads. It's this biographical story and you really wanna get some of this stuff off your chest about what happened in Russia and how wrong you think that was. But you've also got this agenda of wanting to talk to people about the beauty of mathematics and how that's not shown enough. What should someone take from the book? What were you trying to accomplish? What was your main goal?

EF: Interesting enough, what I discovered through this process is that

whatever the author thinks, they're doing. Will not be the case… but true because there could be some unconscious motives which he or she is not aware of. So that certainly was the case for m. Here's how I would describe… if you and I had spoke about it, you know, in 2012, '13, when I was writing it. So the analogy I make is imagine an art class in which they only teach you how to paint fences and walls but never show you the paintings of the great masters. Then of course you will say, I hate art. But in fact what you would really be saying is I hate painting the fence, and so it is with mathematics, we teach our children to teach them how to paint fences and never show them the mathematics of the great masters, right? So and for me being exposed to all this I just felt ashamed that we, mathematicians, are not finding ways… of course it's more abstract than art in some ways, you know? So and there are no museums already now, although now more and more math museums appear as well. I felt this urge to share. I thought it was such a shame. I was really ashamed that I'm not doing enough. So here's what I'm going to do, I'm going to write this book and I'm going to let other people see that beauty that I can see.

BH: So you were gonna like showcase some of the masterpieces?

EF: Yes! But how to do it? Because I understand it's difficult.

BH: Yeah.

EF: And I tried to do it other ways and I could see how difficult it is so I decided to wrap it in a personal story, as a kind of trick to show this kid who is so excited about the subject and then he faces obstacles, has to overcome them and yet he has this drive. But why? Because he finds it beautiful, but what is about… so the reader would then come, I thought would come across this and say, what did he find so exciting? And that's when I will explain.

BH: Yeah.

EF: And the reader would be well motivated to listen. You see?

BH: Because there's a character they want to… empathize.

EF: There is a character. It's a story and yes so that was the idea. But what I realized later is actually I had to tell the story to myself also. Because a lot of that I was… I knew this as a third… in a third person. Not in a first person. I did not fully identify myself with that kid who was ruthlessly treated. Unfairly treated at that time. So as I was writing it, it brought me close to that… to myself, right? So however interestingly enough when I was writing I think, what was… who was writing? It was the sixteen year old who was writing. So I think this way I was able to connect to the readers. It was not Edward who was you know in his forties at the time who was writing but… I was not yet communicating with my sixteen year old. But I allowed him to write. To speak. His voice to be heard through the book because I wanted the book to be successful you see. And interesting enough through this process I got to know him more and so soon after the book was published I was actually able to see more clearly not at a conceptual level… oh there was this guy I went there, I sat there, and I did this I did that. But to actually feel, to feel the pain which he felt. Which was tremendous amount of pain.

BH: So do you think the books greatest success is it's ability to tell the story of the pain and Edward's journey, or do you think it's success was showcasing the masterpieces, which is what you set out to do?

EF: But how can you separate the two? [laughs] You see?

BH: When people talk to you about it what do they want…

EF: Both! Both, so but sometimes interestingly enough because sometimes I think the way we communicate with each other, so for example somebody can be

touched by a story because it may actually remind them, of something about themselves, but they may not be ready yet to frame it in these terms. But yet they could be drawn to it. So they might contact me and speak about how they were fascinating by the mathematics of it. But sometimes I can actually feel that actually there is more. So sometimes it is just a straight forward interest in mathematics. But usually it's more than that. I think that it touches upon some, one could say archetypal, you know, things in our lives… because we all have to overcome and we all have to go through pain and suffering. And you know in that sense just like mathematics is universal language so… Pythagoras Theorem means the same thing to everybody right anytime… x squared plus y squared equals z squared. That's why we love mathematics it's because it brings us together. But so do these personal experiences because when you tell me about something that you had to overcome, that you were mistreated and so on and yet you were able to succeed. That you failed and then you were able to succeed, I am with you at this moment because it reminds me of something that happened to me. And that's how we also find that we are not that different from each other. Right so in that sense, these two parallel tracks are kind of… they are meant to be together! Because they are there to remind us of who we are, ultimately.

[gentle piano music]

BH: I have to ask about one other artistic endeavor of yours. This is your controversial… [laughs]

EF: [laughs]

BH: …can I call it controversial?

EF: Yes.

BH: [chuckles] Your controversial film which I have seen… which means I've seen a lot more of your flesh than I may have expected when we first met. Tell

people about what this film is, how it came to be and what happened.

EF: Okay. Well, so first of all, this is crazy kind of thing. So and now in retrospect, so it's been ten years since this film was made, in 2009 in Paris with a group of really amazing dedicated people most of all with my co-director, Reine Graves, who is a French film director. This was really crazy crazy project. And I understand it now more clearly. Again I did not understand at the time so much. But it was sincere. It was a sincere effort, that's what matters in the end. I wanted to do something different. I wanted to… [heavy sigh]… break out of the kind of… I felt, you know, a little bit too… my life to be too circumscribed, too constrained. And of course a lot of it was… I'm not proud for the narcissism of it, in some sense, which kind of comes through a little bit. I want to be this guy on the screen. And of course yes, I did have this aspirations to be seen, you know, my naked body and so on. You know? Okay I admit of course. But it was not only that, so. There was more and so I was actually criticized for this film.

BH: Can you describe like just in a nutshell what the film is, for people who are unfamiliar with it? So that it makes more sense.

EF: Okay. Well, I mean in some sense there are spoilers.

BH: Yeah.

EF: But okay so at this point I guess it doesn't… whoever wants to see it… it is available by the way online.

BH: Oh Okay.

EF: On a very nice website called labocine.com. First of all it's a homage to Japanese film by the great author Yukio Mishima who also himself played in his film.

BH: Right.

EF: Which was called Rights of Love and Death, and our film is called Rights of Love and Math. So that came before the book, so in fact the title of the book was a riff on the title of the film.

BH: Okay.

EF: And but they're unrelated. Although they're related by the idea of trying to show mathematics in an unconventional way. In the case of a film the idea was to have mathematical formula not written on a black board, but tattooed on a body.

BH: Yeah.

EF: And I think actually its a very good idea by itself because it kind of shows you that mathematics gets under your skin. So it kind shows this visceral character of it. So that a story of a researcher, story of a mathematician, a truth seeker if you will, it is a romantic story in some sense.

BH: I'll tell you what as well, Ed, you were before you time, because these days when I meet young people and mathematicians, everyone has mathematic formulas and things to do with mathematics tattooed on their body.

EF: Well thank you for saying that, so…

BH: Yeah.

EF: For me it was just an insight. It was just this a boom, it just came to me. And I was collaborating with this amazing french director and we bouncing ideas for a few months in 2009 about how to make a film where a viewer would be just kind of… we kind of wanted to shock the viewer a little bit. To just

mathematics in a way which nobody ever had seen it before. And then suddenly you know what, what if we had a tattoo of a formula. And so then and one thing led to another and then we came up with this story and it's kind of a… it's a fairytale, it's a kind of a mythical story. And it is actually unfolding on stylized stage of a Japanese Noh theater. So it's a homage to this Japanese film, although the story is totally different. The premise of the film is that a mathematician played by me [laughs] of course… a mathematician finds a formula of love. So what happens next? Right. So he is elated that he has found this source of eternal love and beauty but of course… and youth… but of course the formula has a flip side. It can be misused. It can be used for evil, he discovers it quickly and now he is being chased by these sort of evil people. That are not specified. But actually see ten years ago I saw that which many of us are very much aware of the dangers of mathematics through surveillance, through actually the very first Numberphile I did was about the NSA putting a backdoor in a popular encryption algorithm, right?

BH: Yeah.

EF: So some years before that I was already kind of interested in this idea that mathematics could be misused and used for evil. Also artificial intelligence, and all this stuff, so that is very much in the media, in the news, in the public domain. At that time it was not so widely discussed in 2009. So that was one thing I was interested in. So he's being chased but of course there is a woman, there is a woman he is love with. And he wants to make tattoos of this formula on her body. Now a lot of people took this literally. And they were offended by this because they said why is mathematician a man and his love interest is a woman. I think a lot… many people who complained most of them actually did not see the whole film but maybe a trailer. And maybe they got slightly wrong idea but I think if they see actual film from beginning to end. And it's only twenty-six minutes. I think they may actually see it's not… how to say. It's not so trivial, you know. Yes, I agree and I am kind of… in retrospect maybe it would be more… it would make more sense to reverse the genders.

BH: Okay.

EF: Because I personally think that… and am not just being facile, or facetious, but I really mean it, I think that under-representation of women and minorities in general in mathematics is the single most important problem that we have to deal with. Because a lot of other things are consequences of that. And definitely we have to make an effort to bring more young women and minorities to mathematics. And be more… not just bring but be supportive, be compassionate. Be aware of the plight of the difficulty of being in a minority, you know? So it's not something to say as slogan but something that requires sustained effort. Having said that, the film was very personal for me and I see now it more clearly because actually I was both that man and that woman. So because in the end he kills himself, but she… at the end of the film she actually rises with that formula on her…

BH: On her body.

EF: On her belly! So that was me. I wanted to be reborn. That feminine side which I had felt perhaps suppressed for many years, it wanted to burst out. So for me it was very personal, so the gender role distribution was a consequence of that very very personal character of this film. I could not articulate at the time. Actually I understood this later. Some people… interestingly enough some viewers saw it right away. That what I was talking about. I did not know it. I understood much later. And I saw very clearly that this was my desire, my wish to become more whole. More myself, to know who I am, to become more whole and more at peace with myself. And that included and required in fact reconnecting to my feminine side, also. So that moment in my mind in that film, that was me, that was that part… you see what I mean?

BH: Yeah.

EF: And so , so and of course she is… who is she? So the whole thing is a fairytale so we don't have to take it literally. She is mathematics herself. She is the truth. And in fact there is a painting on the wall which says, The Truth in Russian. So there's lot of stuff which is woven into it and I would just invite anybody who comes across this film not to rush to judgement or conclusions but try to see it and try to… try this to speak to you, not in conceptual terms but in more visceral terms. And see what you come out with. And of course nowadays we are so quick to label things and so on and so if somebody wants to label then maybe it's not for them this film. But I think somebody who wants to contemplate, who wants to see what is it like to experience something… because for us it is like a tattoo for us, because tattoo is painful, you know? I actually don't have any tattoos myself, but I know people who have and so its painful. But so is discovery in mathematics. It does not come for free. Nothing comes for free. You have to make an effort. And it's a metaphor for that. That it gets under our skill, and we carry it with us. Like a baby. One could say like a baby. That tattoo is made on the belly, you know, it's like his baby, you know? He's dead, he's gone but she… he… survives in that formula which is eternal.

BH: In the film Edward's character does the tattoo, and it is an actual formula, is it?

EF: Yes.

BH: Does it mean something?

EF: Oh yes it does. And it is from quantum physics of course [laughs] it's from one of my research papers with my two good friends physicists Andrei Losev and Nikita Nekrasov. Two Russians. Brilliant physicists. You know when we were making the film the question arose, which formula? So of course we don't want to do something cliche like E equals MC squared. Which is already well know, and so then I was like continuing this narcissistic streak I was like…

BH: [chuckles]

EF: I want it to be my formula. Formula from one of my papers.

BH: Yeah.

EF: So I did a casting [laughs] so I was like leafing through my papers…

BH: Okay.

EF: …to find something which kind of looks nice, you know?

BH: Okay.

EF: captivating, not just meaningful but also… because actually if you look at it… a lot of people kind of were touched by it I think. Got a lot of comments just that still image of the tattoo on the body. It's like wow, you know? So if… I felt if wrote the formula on a blackboard [chuckles] and tried to explain it most of the audience would walk out. But here we could… I think people could feel that energy of it. That it's not... spurious, it's not superficial mathematics. It's not… devoid of passion. It is not separate from our lives. It is actually a product of passion. A product of love. Everything that we do with our heart is something that is meaningful, and something that is like a work of art in some sense.

BH: Was it one of the more obscure formulas? Or was it like a key plank of one of your papers?

EF: It was a very important formula, from our paper.

BH: Okay, okay.

EF: Oh yes, definitely.

BH: It wasn't just like a footnote on page eight that looked nice? [chuckles]

EF: Oh no, no no. No it's very… I'm very proud of this formula and I think it still hasn't been fully explained actually.

BH: Has it got a name?

EF: In the movie it's called Formula of Love, [laughs]

BH: yeah. What's it called in your paper?

EF: It has a certain numbering… I don't know. five point seventeen or something but…

BH: oOkay. yeah.

EF: When… I know when I have show the film in various… at film festivals and stuff like, so invariably somebody would ask, so is this the Formula of Love, you know? [laughs] So…

BH: How do you feel when you watch the film now? Cause talking to you I get like a feeling like… a feeling that you are proud of it but there's also like regrets or things that you would do differently, like how do you look at it now?

EF: I had a very complicated relationship with it. So I kind of didn't like it when it was… for many years. I was uneasy about it and it is a crazy thing. You know? I kind of like cannot believe I did this… honestly.

BH: [laughs]

EF: I mean it's really crazy. But I am proud of it and I hadn't watched it for a

long time and then a couple of years ago I watched it again. And it suddenly hit me what it was about, you know? And it was kind of emotional moment for me because when I saw what was unspoken. I was not ready to consciously… I was not consciously aware of a lot of things happening inside me and they spilled over on screen, you know, in this way. In this weird way, it is a weird film, I mean there's no question. So…

BH: There's not a lot of talking in it. For people who…

EF: It is silent!

BH: Yeah it is a silent film… with music.

EF: With Wagner! With… Richard Wagner's Tristan and Isolde. My god it's incredible. That music.

BH: Yeah.

EF: And to have that. But I owe that… we owe that to Mishima because his film also had a Wagner score, although a different recording and different parts of the opera. But there are a lot of interesting things in there. Hidden things. So one thing maybe I write a book about it, because there are so many references which are I think people may not even be able to realize. So I have a complicated relationship with it. The way I see it now it… one could argue about its merits and so on. It's unusual film, it's a weird film. But what's… it was something that was necessary for me at the time. Without this film there wouldn't be my book, you know? Without it I would not be able to understand certain things about myself.

[violin music]

BH: We often hear like you know mathematicians do their best work when

they're young. You know, we have the Fields Medal for under forty year olds and things like that.

EF: Right.

BH: Is your best work behind you? Or is your best work ahead of you? But also is your best work mathematics or artistic? Because you seem to like doing the arts and the math stuff now.

EF: [laughs] Well I sure hope my best is ahead of me. [laughs]

BH: Yeah?

EF: I may not be… actually interestingly enough, a lot of people know me not from my research, not from my book, but from my Numberphile videos. [laughs]

BH: [chuckles] Well then I hope your best work is ahead of you.

EF: So that's how I might be remembered actually, Brady. [laughs]

BH: [laughs] Well you need to make more Numberphile videos then. [laughs]

EF: Yeah perhaps, perhaps. [laughs]

BH: [laughs]

EF: And so… yeah I don't know I mean I was just… I gave this talk in July at it was a public lecture in Sweden and I was quoting from a great compatriot of mine Sophia Kovalesky who was a Russian mathematician and she was the first woman mathematician who in Western history, you know Western civilization's history as far as we know who was a university professor… who had a PhD, was a university professor… was an editor of a prestigious mathematics journal, that

was in the second half of 19th century and in Sweden in Stockholm, even though she was not allowed to take courses in Germany for instance. She was a student of great German mathematician Weierstrass but he had to teach her privately because being a woman she was not even allowed to sit in let alone be registered. So of course there is some parallels with… [laughs] I can see some parallels, you know?

BH: Yeah.

EF: And so maybe that's why I feel with certain kinship with her. And she was also a writer. She was a great writer. She wrote a number of books which were successful, and she died a t a very young age. She was barely forty, from tuberculosis unfortunately. But absolutely brilliant human being and mathematician and writer and everything else inbetween. And so she wrote in a letter to somebody that you could not be a mathematician without being a poet at heart. A poet is someone who sees thing differently, sees farther than other and that's the job of mathematician as well. And I was really struck by this and when I was giving this lecture in July and then I kind of blurted it out, I wasn't preparing to say that but I said you know actually you don't have to be a mathematician to be a poet, you know, so anything you do that really comes from something deep inside that you really care, something we say from the heart but maybe it's a bit over used this expression. So let's just say from passion, that you are passionate about. Something you are passionate about is poetry. That's what it is and so it's so easy to forget. So a lot of my math I would say is poetry, but some of it is not. So and it's okay, you know, there's certain things which are routine and so and so you can of do, but there are certain bursts of inspiration and I think we live for that, and it doesn't have to be math, it can be… or you know it doesn't have to be even a profession, it could be something in one's personal life. Helping somebody… that's passion too, that's poetry. And so in that sense I don't really care anymore, I guess, if I'm remembered as a mathematician or whatever, or if I'm remembered, you know, it doesn't matter. So it's more like do I do the right thing right now, do I do something… do I

follow my passion today? So for instance I come to this to speak to you, Brady, and I honestly I say no to everybody these days, I don't want… there was a time in my life when I was super interested in being on the stage and being like…

BH: Hmm.

EF: You know getting accolades and applause and so on. I really don't care so I care when it's meaningful and so I know you. That you do some… you do really incredible work with Numberphile and I deeply appreciate so when you give me this opportunity to speak I said yes without thinking because…

BH: Thank you.

EF: It's just I feel like part of the family of Numberphile.

BH: Yeah!

EF: And so it's a pleasure to speak, you know? So that's to me an example of something I did today which was from the heart. From the passion, you know? So it's real and I can sleep well tonight, you know? [laughs]

BH: Okay, what's the thing you're chasing now though, is there something in the Langland's program that I won't understand, like is there?

EF: Oh yes!

BH: So there is… what do you… what's motivating you in your passionate for mathematics now? There is a result out there you want, or a…?

EF: Yes, so there is this new version of Langland's program which I'm working on now. Kind of a new strand, you know, if you will, like a DNA, a new strand. With two great colleagues, one of whom was actually my classmate in

Moscow, in this Oil and Gas place.

BH: Right?

EF: Believe it or not, but we never collaborated. He's a professor at MIT, his name is Pavel Etingof and the other one…

BH: It sounds like that Oil and Gas University it produced some pretty good mathematicians.

EF: Yeah! Oh my god, yes! If you look at the list, it's like wow, you know, there's some really…

BH: Yeah?

EF: I'm really proud to be from that school. And it's a separate story that I'm really grateful to that university, and it was not easy for them to do what they did. They gave us home, which was really really nice. But the second co-author was my actually one of my mentors when I came to Harvard, he's now a professor in Jerusalem, his name is David Kazhdan. So it's a very exciting project I've been working on with them for the last year and just this morning I was spoke with David on Skype, you know he's in Israel, I'm here. So it's like it's really exciting.

BH: Are you winning that battle or losing? Who's winning [laughs] against the…

EF: We are going I think we're doing great. I think we're, yes, we'll keep progressing.

BH: I have one more question. What happened to Evgeny? Did you say in touch with him?

EF: Yes! We have been in touch, yes, by email. I haven't seen him in long time.

BH: He's still alive?

EF: Yes, he is. Yes his health was not so great recently, I'm keeping my fingers crossed but…

BH: But he got to enjoy your success?

EF: But he read my book where I speak about him.

BH: Yeah?

[gentle music fades in]

EF: And he was happy about it, I say sometimes that my book is a love letter to my teachers you know? It's like… that's really the real heroes in this story.

[music fades up]

BH: For more about Edward's work and of course to check out his book see the links down in the notes. I'll also put some links there that Edward has recommended, other stuff you might want to read or see and of course I'll also put a link to Edward's Numberphile videos. [music continues] This podcast was recorded at the Mathematical Sciences Research Institute, which is a great supporter of Numberphile and we'd also like to thank our episode sponsor Meyer Sound, they're an audio engineering company, also based in Berkeley. Have a look at the notes for more links. I'm Brady Haran, this is the Numberphile Podcast, and we'll be back in your feeds again very soon.

[music slowly fades out]