The following is a conversation with Edward Frankel, one of the greatest living mathematicians, doing research on the interface of mathematics and quantum physics with an emphasis on the Langland's program, which he describes as a grand unified theory of mathematics.
He also is the author of Love and Math, the heart of hidden reality.
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be generated by AI. The thoughts coming from my mind will soon be generated by AI. The entirety of wisdom will be generated by language models, large language models that form deep representations,
compressions of human knowledge and are able to access, search, query, integrate, and generate wisdom far, far better than I ever can, which is why I will not be generating wisdom. I will be sitting in a couch with a zen-like look on my face, appreciating every single moment that passes by as I slowly put some macadamia nuts in my mouth and say, damn, it's good to be alive. Go to houseofmacadamias.com slash lex to get 20% off your order for every order. The listeners, that's you, will also get four ounce bag of macadamias when you order three or more boxes of any macadamia
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used for many, many years to bring me joy and happiness. Well, that's not necessarily the feature itself, but it did do that for me because it's a simple piece of software that does one thing. It does it extremely well. It's fast, works on any operating system, and it gives you a basic first layer of protection of your privacy on the internet. Everybody should be using a VPN, at least part-time when you're doing all the kinds of shady stuff you do on the internet, which I'm talking to you, I know you're doing. Anyway, VPN is definitely a thing you should be using in your toolkit of protecting, of securing yourself in the digital space in this increasingly sophisticated cyberspace that we are increasingly spending more and more time in. And my favorite VPN, the one I've used for many years, the one I swear by is ExpressVPN. I've used them for long, long, long, long time before they were ever sponsored. So we flirted for a while, we dated for a while, and now we're fully committed together and married and not looking for any extramarital affairs in case you're wondering. I'm happy. I'm happy on Linux. I'm happy on Windows, on Android, on every single iPhone, everything I got, every device got ExpressVPN on it, and I'm happy. And if you want to be happy like me, go to expressvpn.com slash lexpod for an extra three months free. This is the Lex Friedman podcast. To support it, please check out our sponsors in the description. And now, dear friends, here's Edward Franco.
You open your book, Love and Math, with a question,
how does one become a mathematician? There are many ways that this can happen. Let me tell you how it happened to me. So how did it happen to you? So first of all, I grew up in the Soviet Union in a small town near Moscow called Kolomna. And I was a smart kid, you know, in school, but mathematics was probably my least favorite subject. Not because I couldn't do it. I was, you know, a straight A student, and I could do all the problems easily. But I thought it was incredibly boring. And since the only math I knew was what was presented at school, I thought that was it. And I was like, what kind of boring subject is this?
So what I really liked was physics, and especially quantum physics. So I was buying, I would go to a bookstore and buy popular books about elementary particles, and atoms, and things like that, and read them, you know, devour them. And so I thought my dream was to become a theoretical
physicist and to delve into this finer structure of the universe. So then something happened. When I was 15 years old, it turns out that a friend of my parents was a mathematician, who was a professor at the local college, was a small college preparing educators and teachers. It's a provincial town, imagine it's like 117 kilometers from Moscow, which would be some like 70 miles, I guess. You do the math. I like how you remember the number exactly. Yeah, it's not funny how we remember numbers. So his name was Yevgeniy Yevgenovich Petrov. And if this doesn't remind you of the great works of Russian literature, that you haven't read them, like War and Peace, you know, like with the patronymic names, but this was all real, this was all happening. So my mom one day by chance met Evgeniy Evgenovich and told him about me, that I was a bright kid and interested in physics. And he said, oh, I want to meet him. I'm going to convert him into math. And my mom was like, nah, math, he doesn't like mathematics. So let's say, okay, let's let's see what I can do.
So I went to see him. So I'm about 15. And a bit, a bit arrogant, I would say, you know, like every teenager. So he says to me, so I hear that you are interested in physics and elementary particles. It's like, yeah, sure. And so for example, do you know about quarks? And I said,

yes, of course I know about quarks. Quarks are the, you know, constituents of particles like protons and neutrons. And it was one of the greatest discoveries in theoretical physics in the 60s that those particles were not elementary, but in fact, had the smaller parts. And he said, oh, so then you probably know representation theory of the group as you three. As you worked. So in fact, I wanted to know what was what were the underpinnings of those theories.
I knew the story, I knew the narrative, I knew kind of this basic story of what these particles looked like. But how did physicists come up with these ideas? How were they able to theorize them? And so I remembered, you know, like it was yesterday. So he pulls out a book.
And it's kind of like, like a Bible, you know, like a, like a substantial book. And he opens them, it's somewhere in the middle. And there I see the diagrams that I saw in popular books. But in popular books, there was no explanation. And now I see all these weird symbols and equations.
It's clear that it is explained in there. Oh my God. He said, you think what they teach you at school is mathematics? It's like, no, this is real mathematics. So I was instantly converted. That you understand the underpinnings of physical reality. You have to understand what SU three is. You have to learn what are groups, what is group SU three, what are representations of SU three. There was a coherent and beautiful. I could appreciate the beauty, even though I could not understand heads and tails of it. But you were drawn to the methodology, the machinery of how such understanding could be attained? Well, in retrospect, I think what I was really craving was a deeper understanding. And up to that point, the deepest that I could see was for those diagrams,
but for that story that, you know, a proton consists of three quarks and a neutron consists of three quarks, and they're called up and down and so on. But I didn't know that there was actually underneath, beneath the surface, there was this mathematical theory.
If you can just link, what drew you to quantum mechanics? Is there some romantic notion of understanding the universe? What is interesting to you? Is it the puzzle of it? Or is it like the philosophical thing? Now I am looking back. Yeah. So whatever I say about Edward at 15 is colored by my, you know, all my experiences that happen in the meantime. I should say my current views and so on. For the people who may not know you, I think your book and your presentations kind of revealed that that 15 year old is still in there somewhere. Well, I take it as a compliment. Some of the joy. He's probably still here now. Yes. Yeah, in some way. Yeah, I think it was a joy of discovery and the joy of going deeper into the kind of the, to the root, to the deepest structures of the universe, the secrets, the secrets. And we may not discover all of them. We may not be able to understand, but we're going to try and go as far and as deep as we can. I think that's what was the motivating factor in this. Yeah, there's this mystery. There's this dark room. And there's a few of these mathematical physicists. They're able to shine a flashlight briefly into there. We'll talk about it, but it also kind of makes me sad that there's so few of your kind that have the flashlight to look into the room. It's interesting. I don't think there are so few, to be honest, because I think I find a lot of people are actually interested. If you talk to people, you know, like some people, you wouldn't expect to be interested in this from all walks of life, from people of all kinds of professions. I tell them I'm a mathematician and they, I'm a mathematician.

Okay, so that's a separate story. A lot of people I think have been traumatized by their experience in the math classes. We can talk about it later. But then they ask me what kind of research
I do. And I mentioned that I work on the interface of math and quantum physics. And their eyes light up and say, oh, quantum physics or like Einstein's relativity, I'm really curious about it. I watch this podcast or I watch that podcast, you know, and I've learned this is like, what do you think about that? So I actually find that actually physicists are doing a great job at educating the public, so to speak, and in terms of popular books and videos and so on. Mathematicians are behind. We're starting to catch up a little bit, have been starting last 10 years, but we're still behind. But I think people are curious. Science is still a very much, you know, something that people want to learn because that's our kind of the best way we know to establish some sort of objective reality, whatever that might be. Yeah. And to figure out this whole puzzle, to figure out the secrets that the universe holds. Things that we can agree on, kind of, you know, like, even though for me, at this point, I always, you know, make an argument that our physical theories always change, they get updated. So you had Newton's theory of gravity, then Einstein's theory, you know, superseded it. But in mathematics, it seems that theories don't change. Pythagoras' theorem has been the same for the last 2500 years. x squared plus y squared equals z squared. We don't expect that next year, suddenly, it will be z cubed, you know? And so that, to me, is actually even more, hints even more at how much we are connected to each other. Because Pythagoras' theory, if you think about it, or any other mathematical theorem, means the same thing to anyone in the world today, regardless of their cultural, you know, upbringing, religion, you know, ideas, ideology, gender, whatever, nationality, race, whatever, right? And it has meant the same to everyone, everywhere. And most likely will mean the same. So that's, to me, kind of an antidote to the kind of divisiveness that we sometimes observe these days, where it seems that we can't agree on anything.
To the political complexity of two plus two equals five in George Orwell's 1984.
I was in the Soviet Union in 1984. And so in many ways, I see that it was present, and the novel was present. But we still have not found a dictator who would actually say two plus two equals five and would demand their citizens to repeat that.
The night is still young.
Has not happened yet, okay?
But it does feel like math and physics are both sneaking up to a deep truth from slightly different angles. And you stand at the crossroads or at the intersection of the two. It's interesting to ask, what do you think is the difference between physics and mathematics, in the way physics and mathematics look at the world?
There is actually an essential difference, which is that physicists are interested in describing this universe, okay? Mathematicians are interested in describing all possible mathematical universes, of which, you know, in some of our work, I still consider myself more of a mathematician than a physicist. My first love for physics, notwithstanding. Mathematicians are, in a way, we have more diversity, if you might say. So we are accepting, for instance, our universe has three spatial dimensions and one time dimension, right? So what I mean is that...
Allegedly.

Allegedly. Absorbed, but that we can absorb today, right? So of course, there are theories where there are some hidden dimensions as well. Well, let's just say observed dimensions. So this tabletop has two dimensions, because you can have two axes, two coordinate axes. X and Y, but then there is also a third one to describe the space of this room. And then there is a time dimension. So realistic theories of physics have to be about spaces of three dimensions or spacetime, so four dimensions. But mathematically, we are just as interested in theories in 10 spacetime dimensions, or 11 or 25 or whatever, or infinite dimensional spaces, you know? So that's the difference. On the other hand, I have to give it to the physicists, we don't have the same satisfaction that they have of having their theories confirmed by an experiment. We don't yet to play with big machines like LHC, in Geneva, a large Hadron Collider that recently discovered, you know, the Higgs boson and some other things. For us, it's all like a mental exercise in some sense. We prove things by using rules of logic. And that's our way of confirming, experimental confirmation, if you will. But I think I kind of envy a little bit, my friends physicists, that they get to experience this sort of, these big toys, you know, and play with them. But it does seem that sometimes, as you've spoken about, abstract mathematical concepts map to reality. And it seems to happen quite a bit. That's right. So mathematics is underpin physics, obviously. It's a language, which the book of nature, as Galileo famously said, is written in the language of mathematics. And, you know, the letters in it are the circle triangles and squares. And those who don't know the language, I'm paraphrasing, are left to wander in a dark labyrinth. That's a famous quote from Galileo, which is very true and has become even more true, more recently, in theoretical physics, in the most far out parts of the theoretical physics that have to do with elementary particles and as well as the structure of the cosmos at the large scale.
What do you think of Max Tagmark, who wrote the book, Mathematical Universe?
So do you think, just lingering on that point, you think at the end of the day, the future generations will all be mathematicians? Meaning the ones that deeply understand the way the universe works. At the core, is it just mathematics? At the core of, you know, I would say mathematics is one half of the core. So the book is called Love and Math. So these are the two pillars, in my view. In other words, you can't cover everything by math. So mathematics gives you tools, it gives you a kind of a clear vision. But mathematics by itself is not enough for one to have harmonious and balanced life. So I am suspicious of any theory that declares that everything is mathematics. So math can generate things that are beautiful, but it can't explain why it's beautiful. Math, you could say, is a way to discern patterns, to find regularities in the universe. And both physical and mental universe, the mathematics explores the mind as much as it explores the physical world around us. And it helps us to find those patterns, which makes our perception more sophisticated, our ability to perceive things such as beauty. And it sharpens our ability to see beauty, to understand beauty. So our world becomes more complex. From thinking that earth is flat, we go to realizing that it is round, that it's shaped as a sphere, so that we can actually travel around the earth. So there isn't a place where we hit the end, so to speak. And then proceeding in the same vein, then Einstein's general relativity theory tells us that our space time is not flat either. This is much harder to imagine that a bent three-dimensional space or four-dimensional space time, because this idea that the space around us is flat is so deeply entrenched. And yet we know from this theory

and from the experiments that have confirmed it, that a ray of light bends around a star, as if being attracted by the force of gravity. But in fact, the force of gravity is the bending. It's just that it's not only the bending of the space, it's also the bending of space-time. There is a curvature not only between spatial dimensions, the way parallels and meridians come together. In a small scale, they look like perpendicular lines. But if you zoom out, you see that the space is curving the space. They are sort of the tracks along which the space gets curved. That would be the curvature of spatial dimensions. But in fact, now throwing time, and one time, imagine a sphere which has one of the meridians correspond to time and the parallels correspond to space. I can't imagine it, but I can write a mathematical formula expressing that curvature. And in fact, that curvature is responsible for the force of gravity, attraction between the sort of simplest instantiation of it, attraction between two planets, or between two human beings. Yeah, the time, bending time, it's not very nice what that theory did to time, because it feels like the marching of time forward is fundamental to our human experience. The arrow of time marching forward nicely seems to be the only way we can understand the universe. And the fact that you can start- Up to now, up to now, there are people who claim that they have the possess other ways of experiencing it. So truly can visualize messing with time? Well, messing with time, but not necessarily messing with time, because one point of view is that, you know, I think who was it? I think William Blake, who wrote that eternity loves time production. So one point of view is that it is eternity, which is fundamental, where time stands still, which our mind conceptualizes as the time. So, but in fact, you know, it's not something mystical. If you think about when you about it, when you're really absorbed in something, time does stand still. And then you look at the clock and it's like, oh my God, two hours have passed. And it felt like a couple of seconds. When you are absorbed, when you're in love, when you are passionate about something, when you're creating something, you are, we lose ourselves and we lose the sense of time and space for that matter. You see, so there is only that, which is happening, that creative process. So I think that this is familiar to all of us. And we may be actually the closest to the truth at that moment. Yes. So yes. So then there is a point of view that this is where we are, we are who we are at our sort of fundamental, at our fundamental level. And after that, the mind comes in and tries to conceptualize it. It's like, oh, because I was writing something. I was writing a book, I was painting this painting, or maybe I was watching this painting and got totally absorbed in it. Or I fell in love with this person. That's what happened. But in the moment when it's happening, you're not thinking about it. You're just there. Yeah, we construct narratives around the set of memories that seem to have happened in sequence, or at least that's the way we tell ourselves that. And we also have a bunch of weird human things like consciousness and the experience of free will that we chose a set of actions as the time unrolled forward. Right. And we are intelligent, conscious agents taking those actions. But what if all of that is just an illusion and a nice narrative we tell ourselves? Sure. That's a really difficult thing to internalize. And imagine that to make it really catch 22. Imagine that our minds are set up in such a way that they can't approach the world or experience otherwise. So in other words, to understand, to see that from a more kind of all encompassing point of view, we have to step out of the mind. Well, I wonder what's the more honest way to look at things. But I think we like to be to play with time. I think we like to play with these experiences, with all the drama of it,

with all the memories, with all the tribulations. We love it. Otherwise, we wouldn't be doing it. I think this or Earth loves it. The evolutionary process somehow loves it. Whatever this thing that's being created here on Earth, it seems to like to create, like to allow its children to play with certain truths that they hold, this subjective truths that are useful for the competition or whatever this dance that we call life broadly define not just humans. And you know, I'm glad you mentioned that because what I find fascinating is that the greatest scientists are on record saying that when they were making their discoveries, they felt like children.
So Isaac Newton said to myself, I only appeared as a child playing on the seashore and everyone's in a while finding a prettier pebble or a prettier shell.
Whilst, I think he said something like the infinite ocean of knowledge was lying before me. Alexander Grohtendig, who probably was the greatest mathematician of the second half of the 20th century, the French mathematician, Alexander Grohtendig, wrote that discovery is a privilege of a child. The child who is not afraid to be wrong once again, to look like an idiot, to try this and that, I'm paraphrasing, and go through trial and error. That is for them, in other words, for them that innocence of a child who is not afraid, who has not yet been told that it cannot be done. That was essential to scientific pursuit, to scientific discovery. And now also compared to Pablo Picasso, a great artist, so who said every child is an artist. The question is how to preserve that as we grow up. Do you struggle with that? You're one of the most respected mathematicians in the world. You're Berkeley, you're like, there's a statue, you're supposed to be very like, you know... Ivory towers. Sometimes I joke, I say, I take an elevator to the top of the Ivory tower every day. Yeah. You're supposed to speak like royalty. Do you struggle to strip all of that away to rediscover the child when you're thinking about problems, when you're teaching, when you're thinking about the world? Absolutely. I mean, that's part of being human, because when we grew up, I mean, all of them, all of these great scientists, I think they were so great in part, because they were able to maintain that connection, okay, that fascination, that vulnerability, that spontaneity, you know, and kind of looking at the world through the eyes of a child. But it's difficult because, you know, you go through education system. And for many of us, it's not especially helpful for maintaining that connection that we kind of like, we're being told certain things that we accept, take for granted and so on. And little by little. And also, we get hit every time we act different, okay, every time we act that doesn't, in a way that doesn't fit sort of the pattern, we get punished by the teachers, get punished by parents, and so on. And don't get respect when you act childlike in your thinking, when you are fearless and looking like an idiot. That's right. Because there's a hierarchy and nobody wants to look like an idiot, you know, once you start growing up, or you think you're growing up.
In the beginning, you don't even think of, you don't think in these terms. You just play, you're just playing, and you are open to possibilities, to these infinite possibilities that this world presents to us. So how do we, I'm not saying that education system should not be also kind of taming that a little bit. Obviously, the goal is balance that acquiring knowledge so that we can be more mature and more discerning, more discriminating in terms of our approach to the world, in terms of our connections to the world and people and so on. But how do we do that while also preserving that innocence of a child? And my guess is that there is no formula for this. It is a life,

is an answer. Every life, every human being is one particular answer to how do we find balance. That's one imperfect approximation, approximate solution to the problem.
We can look up to the great ones who have credentials in the sense that they have shown and they have proved that they have done something that other humans appreciate, our civilization appreciates, say Isaac Newton or Alexander Grottendijk or Pablo Picasso. So they have established their right to speak about these matters and we cannot dismiss them as mere madmen. They say, okay, well, if the same thing was said by somebody who never achieved anything in their field of endeavor, it would be easy for us to dismiss it. But when it comes from someone like Isaac Newton, we take notice. So I think that's something important that they teach us. And especially today, in this age of AI, of course, there's a big elephant in the room always, which is called AI. And so I know that you are an expert in the subject. And we are living now in these very interesting times of new AI systems coming online pretty much every couple of weeks. So I kind of, to me, that whole debate about what is artificial intelligence, where is it going? What should we do about it? Needs an influx of this type of considerations that we've just been talking about. That, for instance, the idea that inspiration, creativity doesn't come from accumulation of knowledge, because obviously a child has not yet accumulated knowledge. And yet the great ones are on record saying that a child has a capacity to create. And an adult credits the inner child for this capacity to create as an adult. You see, that's kind of weird if we take the point of view that everything is computation, everything is accumulation of knowledge that just bigger and bigger data sets, finer and finer neural networks, and then we will be able to replicate human consciousness. If we take that point of view, then what I just said kind of doesn't fit. Because obviously a child has not been fed any training data, as far as we know. Yet they're perfectly capable of distinguishing between cats and dogs, for instance, and stuff like that. But much more than that, they're also capable of that wide-eyed perspective. So can it really be captured, that perspective, that sense of awe? Can it really be captured by competition alone? I don't know the answer, so I'm not sort of trying to present a particular point of view. I'm just trying to question any theory that starts out by saying life is this, or consciousness is this. Because when you look more closely, you recognize that there are some other things at play, which do not quite fit the narrative. And it's hard to know where they come from.
It's also possible that the evolutionary process has created
is the very, it is computation. And the child is actually not a blank slate, but the result of one of the most incredible several billion year old computations that had explored all kinds of aspect of life on earth, of war, and love, and terror, and ambition, and violence, and invention, all of that from the bacteria today. So that young child is not a blank slate. They're actually hold within them the knowledge of several billions of years.
Right. The question is whether as a child, you carry that in the form of the kind of computational algorithms that we are aware today. You see, what strikes me as unlikely is that, how should I put it? How interesting that, you know, you are a computer scientist, and there are other people, I have studied computer science, so I know a little bit. And so it's tempting to say, oh, the whole world is computer science, or is based, can be explained by computer science. Why? Because it makes me feel good, because I have mastered it, I have learned it. My ego is very happy, and people come to me, and

they look up to me, and they revere me, kind of like priests in old days, when the religion was paramount, when you would tend to explain things in theological religious terms. Today, science has progressed. There are fewer people who kind of buy into official religion, you know. So we have this urge, I suppose, to explain, and to know, and to dissect, and to analyze, and to conceptualize, which is a wonderful quality that we have, and we should definitely pursue that. But I find it a little bit unlikely that the universe is just exactly what I have learned, and not something that I don't know, you see.
Well, there's a lot of interesting aspects of the current large language models that, one perspective of it, I think, speaks to the love and math that you talk to, which is they're trained on human data from the internet. So at its best, a large language model, like GPT-4, captures the magic of the human condition on its full display, its full complexity, and since mimicking, it's trying to compress all the weirdness of humans, of all the debates and discussions, the perspectives, all the different ways that people approach solving different problems, all of that compressed. So we live, we're each individual ants. We only have, like, we have a family, we interact with a few little ants, and here comes AI that's able to summarize, like a TLDR report of humanity. And that's the beauty of it. So I embrace it.
But I wonder if... I'm very impressed by it. I wonder if it can be very impressive, meaning way more impressive in being able to fake or simulate or emulate a human.
And I'm glad you mentioned that, because that seems to be the mantra. It's just fake it till you make it, isn't it? Isn't that what we all do, though?
No. Well, yes, we do that. But we also do other things. We can be truly in love. We can be truly inspired when it is not fake. I do believe. Call me romantic, okay? But I do believe.
And this is a very good... I'm glad you're putting it in these terms, because I've had conversations like that, that, yeah, fake it till you make it, but that's what humans do. Yes, we do that, but not all the time. And that is debatable, because also I speak from my own experience. And that's where the first person perspective comes in, the subjective view. I cannot prove to you, for instance, or anyone else, that there are certain moments in my life where I am genuine, I am pure, so to speak, when it's not faking it. But I do have a tremendous certainty of it. And that's a subjective certainty. Now, I am, as a scientist, I'm also trained to give more credibility to objective arguments that are things that can be reproduced, things that I can demonstrate, that I can show. But as I get older, as I get more mature, hopefully, I'm starting to question why I am not giving as much credibility to my subjective understanding of the world, the kind of the first person perspective.
When actually modern science has already sold on that, quantum mechanics has shown unambiguously that the observer is always involved in the observation. Likewise, Gödel's incompleteness theorems, to me, show how essential is the observer of the mathematical theory. For one thing, that's the one who chooses the axioms. And we can talk about this in more detail. Likewise, Einstein's relativity, where time is relative to the observer, for instance.
That's brilliant. You're just describing in all of these different scales, the observer, what the observer means. That's right. So science of 19th century had, from modern perspective, and I don't want to offend anybody, had the delusion that somehow you could analyze the world being completely detached from it. We now know after the landmark achievements

of the first half of the 20th century that this is nonsense, that it's simply not true.
And this has been experimentally proved time and time again. So to me, I'm thinking maybe it's a hint that I should take my first-person perspective seriously as well and not just rely on kind of objective phenomena, things that can be proved in a traditional sort of objective way by setting up an experiment that can be repeated many times. Maybe I fall in love in the party, the deepest love of my life, perhaps hasn't happened yet. Perhaps I will fall in love, but it's a unique event. You can't reproduce it necessarily, you see. So in that sense, you see how these things are closely connected. I think that if we are declaring from the outset that all there is to life is computation in the form of neural networks or something like this, however sophisticated they might be, I think we are from the outset denying to ourselves the possibility that, yes, there is a side of me which is not faking it. Yes, there is a side of me which cannot be captured by logic and reason. And you know what another great scientist said, Blaise Pascal? He said, the heart has its reasons of which the reason knows nothing. And then he also said, the last step of reason is to grasp that there are infinitely many things beyond reason.
How interesting, this was not a theologian, this was not a priest, this was not a spiritual guru. It was a hardcore scientist who actually developed, I think, one of the very first calculators. How interesting that this guy also was able to impart on us that wisdom. Now, you can always say that's not the case. But why should we, from the outset, exclude this possibility that there is something to what he was saying? That is my question. I'm not taking sides. What I'm trying to do is to shake a little bit the debate because most mathematicians that I know and computer scientists
even more so, they're kind of already sold on this. It reminds me of this famous Lord Kelvin's quote from the end of 19th century. There's some debate whether he actually said that, but never let a good story stand in the way of truth. He said, physics is basically finished.
All that remains is more precise measurement. So I find a lot of my colleagues are happy to say, everything's finished. We got it. We got it. Maybe a little tweaks in our large language models. So now, here's my question. I'm kind of playing devil's advocate a little bit because I don't see the other side of what represented that much. And I'm saying, okay, could it be also that if you believe in that, that that becomes your reality, that you kind of put yourself in a box where everything is computation, and then you start seeing things as being such. It's confirmation bias, if you will. This also reminds me that I think a good analogy is, as a friend of mine, Philippe Koshin told me that in France, there is this literary movement, which is called Ulipo, O-U-L-I-P-O. And it's a bunch of writers and mathematicians who create works of literature where, in which they basically impose certain constraints. A good example of this is a novel, which is called The Void or Disappearance by a writer named Georges Perec, which is a 300-page novel in French, which never uses the letter E, which is the most widely used letter of the French language. So in other words, he set these parameters for himself. I'm going to write a book where I don't use this letter, which is a great experiment and I applaud it. But it's one thing to do that and to kind of show his gamesmanship, if you will, and his ability as a writer. But it's another thing, if at the end of writing this book, when you finish the book, he would say letter E actually doesn't exist.
And he tried to convince us that, in fact, French language does not have that letter, simply because he was able to go so far without using it. So self-imposed limitation,

that's how I see it. And I wonder why we should do that. Do we really need,
do we really feel the urge to say the world is like that? The world can be explained this way
or that way. And I'm saying it, it's a personal question for me, because I am addicted to knowledge
myself. Hi, my name is Edward. And I'm a knowledge addict. I'm being serious, I'm not
being facetious. Up until very recently, maybe a couple of years ago, I simply did not feel
comfortable if I could not say, give an answer, explanation. It's like, oh, there has to be
some explanation. And I try to frantically search for it. Just for somebody like me,
and I heard, you know, a left brainiac. And, you know, that's kind of typical for scientists,
for mathematicians. It is incredibly hard just to allow the possibility that it's a mystery
and not to feel the urge to get the answer. It is incredibly hard. What's possible? And it is
liberating. It's a recovering addict to knowledge. Let me say what you gain from it. For instance,
I understand the value of paradoxes. I appreciate paradoxes more. And, you know,
to use another philosopher, Soren Kierkegaard, the Danish philosopher said, I think without
paradox is like a lover without passion. A paltry mediocrity.
Oh, that's a good line.
All right. So, and, you know, Niels Bohr, Niels Bohr said, in Simer Vane, the great Danish also.
There's something about Danes. I think it all started with Hamlet, you know.
He said the opposite of a simple truth is a falsity. But the opposite of a great truth
is another great truth. In other words, things are not black and white, you know, they're not,
and I would even venture to say the most interesting things in life are like that.
The ones which are ambiguous. It's an electron, a particle, or a wave. It depends how you set up
an experiment. It will reveal itself as this or that, depending on how you set up an experiment.
This bottle, if you project it down onto the table, you will see more or less a square.
If you project it onto a wall, you will see different shape. A naive question would be,
is it this or that? We understand that it's neither. But both projections reveal something.
They reveal different sides of it. A paradox is like that. It's only paradoxical if we are confined
in a particular vision, if we are wedded to a particular point of view. It's a harbinger,
if you will, of a possibility of seeing things as they are more sophisticated than we thought before.
That's such a difficult idea for science to grapple with. I don't know how there's so many
ways to describe this, but you could say maybe that the subjective experience of the world
from an observer is actually fundamental. But we know that. Our best physical theories tell
us that unambiguously. In quantum mechanics, actually, Heisenberg captured the best when
he said, what we observe is not reality itself, but reality subjected to our method of questioning.
When I talk about electrons, for instance, there is a very specific way in which
this is realized. There is a so-called double slit experiment. For those who don't know,
you have a screen and you have an emitter from which you shoot electrons. In between,
you put another screen which has two vertical slits parallel to each other. If we were shooting
tennis balls, each ball would go through one slit or another and then hit the screen behind
this or that slit. Let's say they're colored, they're painted. There will be bumps or spots
of paint behind this or that. But that's not what happens when we shoot electrons. We see
an interference pattern as if we were actually sending a wave so that each electron goes through
both slits at once and then has the audacity to interfere with itself, where at some points,
two crests would amplify and at some points, a crest in the trough would cancel each other.

Yet, so that suggests, okay, so the electron is a wave, not so fast because if you put a detector behind one of the slits and you say, I'm going to capture you, I'm going to find out which slit you went through, the pattern will change and it will look like the particles.
That's a very concrete realization of the idea that depending on how we set up an experiment, we will see different results. The problem is that our psyche, I feel, is lagging behind, in part because maybe our scientists are not doing such a great job, so I take responsibility for this, that why haven't I explained this properly? I tried in a bunch of talks and so on, so now I'm talking about this again. Our psyche is lagging behind. Even though our science has progressed so much from the certainty and the determinism and all of that, of the 19th century, our psyche is somehow still attached to those ideas, the ideas of causality, of this naive determinism that the world has a bunch of billiard balls hitting each other, driven by some blind forces.
That's not at all like it is and we've known this for over, well, for about 100 years at least.
You know? And you call this self-imposed limitation.
It is a self-imposed limitation when we pretend that, for instance, that this naive ideas of 19th century physics are still valid and then start applying them to our lives and then also derive conclusions from it. For instance, people say, there is no free will. Why? Oh, because the world is just a bunch of billiard balls. Where is the free will? But excuse me, didn't you get the memo that this has been debunked thoroughly by the so-called quantum mechanics,
which is our best scientific theory? This is not some kind of bullshit or some kind of, you know, concoction of a madman. This is our scientific theory, which has been confirmed by experiment.
So we should pay attention to that. But of course, it's not just self-imposed limitation.
Unfortunately, in this case, there is a big issue of education.
So a lot of people are not aware of it through no fault of their own, because they were never properly taught that because our system is broken, education system is broken, especially math.
And then our, so where do we get the information? You get information from our scientists who actually write popular books and so on, which is a great, you know, great thing that they do.
But a lot of scientists somehow, when it comes to explaining the laws of physics, they're doing a fantastic job talking about this phenomenon, for instance, double slit experiment and things like that. But then, you know, interviewed by Science Magazine about free will and so on, they revert back to 19th century physics, as if those developments actually never happened. So to me, this is single most important sort of issue in our popular science. The idea that somehow there is this world out there, but it's complete, has nothing to do with me. So I can, I can revel in the intricacies of these particles and their interactions, but completely ignore what implications this has for my own relationship to physical reality, to my own life, you know, because it's kind of scary, I guess, you know.
But also, what are the tools with which we can talk about the observer, the subjective view on reality? What are the tools with which we could talk about rigorously talk about free will and consciousness? What are the tools of mathematics that allow that? I don't think we have those tools.
Because we haven't been taught properly. So actually, tools are there. For instance, I think, well, here we have to, I have to say, my conviction is that everybody knows.
In the heart of hearts, everybody knows that there is that. There is something in a football. There is something mysterious. And in fact, you know, somehow immediately,

I feel that, you know, the impulse to quote somebody on this, because as if, as if my own opinion doesn't go. There's a long dead expert that has said that.
When Einstein said that, you know, so like, how, see, look at me. I am supposedly like this smart, intelligent person. I am afraid to say it and own it myself. I have to find confirmation. I have to find an authority who agrees with me. And in fact, it's not so difficult to find because Albert Einstein literally said the most important thing in life is the mysterious. Okay, he actually said that there are some quotes which are attributed to him, which he never said, but this he did. I investigated. Okay. So, but more importantly, you know, how do you feel about it? I think that everybody knows. But in other words, he also said Einstein, imagination is more important than knowledge. Okay. And he explained, for knowledge is always limited. Whereas imagination embraces the entire world, giving birth to evolution. It is strictly speaking, a real factor in scientific research, he says. And he says, I am enough of an artist to follow my intuition and imagination. That's Albert Einstein again. So, and I feel the same way, to be honest, if I think about my own mathematical research, it's never linear. It's never like, give me more data, give me more data, give me more data, boom, the glass is full. And then I come up with a discovery. No, it's always, it's always, it's always felt as a jump, as a leap. And I have actually been studying various examples in history of mathematics of some fundamental discoveries, like discovery of complex numbers, like square root of negative one. I wonder if a large language model could actually ever come up with the idea that square root of negative one is something that is essential or meaningful. Because if all the information that you get, all the knowledge that had been accumulated up to that point, tells you that you cannot have a square root of a negative number. Why? Because if you had such a square root, we know that if then we would have to, if you square it, you get a negative number. But we know that if you square any real number, positive or negative, you will always get a positive number. So checkmate, it's over. Square root of negative one doesn't exist. Yet we know that these numbers make sense. They're called complex numbers. And in fact, quantum mechanics is based on complex numbers. They are essential and indispensable for quantum mechanics. Could one discover that? So to me, that sounds like a discontinuity in the process of discovery. It's a jump. It's a departure. It is like a child who is experimenting. It's like a child who says, I'm not afraid to be an idiot. Everybody says the adults are saying square root of negative number doesn't exist. But guess what? I'm going to accept it. And I'm going to play with it. And I'm going to see what happens. This is literally how they were discovered. There was an Italian mathematician, astronomer, astrologer. He made money apparently by compiling astrological sort of readings for the elite of his era. This is 16th century as one does, a gambler. All around interesting guy. I'm sure we would have an interesting conversation with him, Gerolamo Cardano. He also invented what's called cardan shaft, which is an essential component of a car. Cardano Vival, we say in Russian. So he wrote a book, which is called Ars Magna, which is like a great art of algebra. And he was writing solutions for the cubic and quartic equations. This is something that is familiar because at school, we study solutions of quadratic equations, equations of degree two. So you have ax squared plus bx plus c equals zero. And there is a formula which solves it using radicals, using square roots. And Cardano was trying to find a similar formula for the cubic and quartic equations for which would start with x cube or x to the power of four, as opposed to x

squared. And in the process of solving these equations, he came up with square root of a negative number, specifically square root of minus 17. And he wrote that I have to forego some mental tortures to deal with it. But I am going to accept it and see what happens. And in fact, at the end of the calculation, these weird numbers got cancelled. They kind of cancelled out. And the formula appeared square root of negative 17 and its negation. So they kind of conveniently gave the right answer, which is not involved those numbers. So he was like, okay, what does it mean? Mental tortures. So you see from the point of view of the thinking mind, it is something almost unbearable. It's almost I feel that a large language model, a computer running a large language model trying to do that would just explode. And yet a human mathematician was able to find the courage and the inspiration to say, you know what, what's this wrong? Why, why are we so adamant that these things don't exist? That's just our past knowledge is based on what our past knowledge is and knowledge is limited. What if we make the next step? Today, for us mathematicians, complex numbers that we call them are not at all mysterious. The idea is simply that you plot real numbers, that is to say, all the whole numbers like zero one and so on, two and so on, right? All fractions like one half or three halves or four over three. But then also numbers like square root of two or pi, we plot them as points on the real line. So we draw this is it. This is one of the kind of perennial concepts, even in our very poor math curriculum at school. But now imagine that instead of one line, you have a one axis, you have a second axis. And so your numbers now have two coordinates, x and y. And you associate to this point with coordinates x and y, the number x, which is real number plus y times square root of negative one. This is a graphical geometrical representation of complex numbers, which is not mysterious at all. Now it took another 200 or 300 years for mathematicians to figure that out. But initially it looked like a completely crazy idea. So all it is, all complex numbers is just an expansion. Real number, two real numbers. The real part and the imaginary part. It's just an expansion of your view of the mathematical world. The fact that you can actually, you can add them up by adding together the real parts and imaginary parts, that's easy. But there is also a formula for the product, for the multiplication, which uses the fact that square root of minus one squared is minus one. And the amazing thing is that that product, that multiplication satisfies the same rules, the same properties that are usual operation of multiplication for real numbers. For instance, there is an inverse for every nonzero number that you can find. Like number five has an inverse one over five. But one plus i also has an inverse, for instance, you know, that was always there in the mathematical universe. But we humans didn't know it. And here comes along this guy who engages in the mental torture, who takes a leap off the cliff of comfort of like mathematical comfort.

Established knowledge.

Established knowledge. Right. And now, obviously, for each sort of fruitful leap like that, there probably were thousands of like things which went nowhere. I'm not saying that every leap, you know, it's like, it's an open shooting game. Because for example, you can try to do the same with three dimensional space. So you have coordinates x, y and z. And you can say, oh, if there's one dimensional, we have a bona fide numerical system called real numbers. If it's two dimensional, which is like, you know, geometrically, it's just like the stable top extended to infinity in all directions. These are complex numbers. And we can define addition and multiplication. And they will satisfy the same properties as real numbers that we're used to.

What about three dimensional space? Is it possible to also define some operation of addition and multiplication on it so that these operations would satisfy the properties that we're used to? And the answer is no. You can define addition, but you can't define multiplication for which there would be an inverse, for instance. So there is something special about the plane, the two dimensional case. And by the way, next question would be what about four dimensional? In the four dimensional space, again, you can and you get what's called quaternions discovered by an Irish mathematician Hamilton in the 19th century. And then in the eight dimensional, there is something similar called octonions. And that's about it. So how interesting. These structures exist in dimension one, two, four and eight, which are all powers of two. Two squared is four. Two to the third power is eight. That's one of the bigger mysteries in mathematics. Why is it so? So that's a hint. That's a hint of what's missing in our high school curriculum. The kind of fascinating mysteries. Yes. The appreciation of the mysterious. So in other words, yes, we resolved this one mystery that we understood that square root of negative one is real, is meaningful. We build a theory to service those numbers, to describe those numbers. Did we find the theory of everything? No, because we then invited other mysteries, because we pulled the veil, so to speak, or we pushed the frontier, and then new things come, get illuminated, which we couldn't see before. That's how I see the process of discovery in mathematics. It's an endless, limitless pursuit. Can you comment on what you think this human capability of imagination that Einstein spoke about of the artists following their intuition in this big Alice in Wonderland world of imagination? What is it? You visit there sometimes. What does it feel like? Yeah, what does it feel like? What is it? What is that place? It feels like playing, but I think all of us are engaged in that kind of play, no matter. When we do what we love, I think it always feels the same. But it's not real, right? So you're describing a feeling, but that place you go to in the imagination, it's bigger than the real world. So there is a big conundrum as to whether mathematics is invented or discovered, and mathematicians are divided on this. Nobody knows. What do you bet your money on financially? Investment advice. So let me tell you something. My views have evolved. When I wrote Love and Math, when I wrote my book, I was squarely on the side of mathematics is discovered. What does it mean? Usually mathematicians or others who have this idea, what I believe, are called Platonists in honor of the great philosopher Plato, who talked about these absolute perfect forms. So for me, about 10 years ago, the world of mathematics was this world of pure forms, this beautiful, pure forms, which existed outside of space and time, but I was able to connect to it through my mind. And as it were kind of dive into it and bring treasures back into this world, into this space and time, that's how I viewed the process of mathematical discovery. How nice, how neat, very neat. Also makes you feel connected to something divine, allows you this sense of escape from the cruelty and injustice of this world, which I now recognize. And the divine world of forms is stable, reliable. Something's stable. In that world, everything is clear cut. It's either true or false. How nice, huh? It's very nice. Oh my God. The biggest illusion of all. Allegedly. I think now. I think now. I understand why I liked it, because I think that I was very dissatisfied with what we call the real world, the world around me, the cruelty, the injustice of it. And I went through certain experiences as a kid, which made me love mathematics even more

as this place where I could be safe and in control.
Made you see the human world as lesser than the mathematical world.
Yes.
As more limited than the mathematical world.
Yes. Yes. And I think that I think that they're still missing the mark in some sense, because in fact, what I now think it's not, it's not, it's, it's a paradoxical question.
The question whether mathematics is invented to discover whether there is this world of pure forms and so on is, is a, is another paradoxical question, which doesn't have a simple answer, like whether electron is a particle or a wave from one point of view. Yes, it's true.
And just the fact that so many mathematicians today actually subscribe to this idea gives it a certain credibility, because that's what we feel. We do feel that we dive into that mindscape, so to speak, but the very structured mindscape where I wrote in Love and Math that enchanted gardens of Platonic reality, where all this fruit is gross, and then we, we, we might, gives you this sort of romantic sense of an explorer. And someone may be stuck in a, you know, some provincial town in Russia, for instance, but have the sense of Magellan, you know, of traveling around the world. It's just not in the world that we usually think of.
So it's, it's one point of view, but the other point of view is that, yes, it is a human process.
Of course it is. I mean, it is, you cannot deny that it's human beings who have so far, discovered new mathematics. And I do not deny the possibility that a computer programs will be able to discover new mathematics, but so far it's been humans.
So it, whatever it is, whether it's discovered or invented, it is a human activity.
Well, that the possibility that paradoxes are actually fundamental to reality and really, really internalizing that, that we exist in a world of not forms, but of paradoxes.
Fingo. And so it's like what I said, but if you think it's weird, and I agree with you, as a recovering addict to knowledge, you know, but I am liking it more and more because there's so much freedom in it. And like, like Nils Bohr said, you know, like quoted that earlier, that the opposite of a great truth is another great truth. He's pointing out to this fact that, you know, and he also said that some, some things in quantum physics are so complicated, the only way you can speak of them is in poetry. So in other words, what is that about poetry? What is about art? Why are we so drawn to that? Why are we so captivated, captivated by, by those forms of, by, they are not intellectual necessarily. They are not, when you look at a painting that you like, when you listen to music, that you love, you get lost in it, you get absorbed in it, it can make you cry, it can make you laugh, it can make you remember something, it can make you feel more confident, it can make you feel sad or happy and so on.
What is this all about? Is it really just some play between something kind of like cellophane play or some neurons hitting on each other? Is it really that only? Maybe.
It could be, it could be both. I'm just worried about kids these days that might live in a world of paradoxes, you know, if there's no God, everything is possible. I mean, I just, they'll have a little too much fun and we have to put a constraint to the fun. Have you looked at the world lately? I haven't checked in in a while. You think it's perfect? The way it is now, the world without paradoxes, the world in which we believe that every question can be answered as yes or no, that it is this or that. And if you disagree with me, you're my enemy.
Wouldn't that be interesting if this 21st century is a transition

into seeing the world as a world of paradoxes? I'm telling you, you know, people predicted that, you know, the age of Aquarius, you know, that the axis of the earth is rotating relative to the plane in which the earth goes around the sun. And the period of this revolution is around 2000 years. So there is a traditional way of measuring that by this eras, you know, the ages. So the previous one was called the Age of Pisces, because of the constellation of Pisces that it points to, so to speak, you know. And now it's, you know, as in famous musical hair, they said the Age of Aquarius is up on us. So the different people dated differently, but somewhere around the time where we are finding ourselves. How interesting, right? There's all the strife and all the difficulties the world is experiencing. This might actually be the transition to something more harmonious. Wouldn't it be nice? It's also interesting that people from long ago are able to predict certain things. It's, and it's almost like from long ago, and you've talked about this with Pythagoreus, that it seems that they had a deep sense of truth. That's right. That's why Permian is all of this, even now. So it's not just a linear trajectory of an expanding knowledge. There's a deep truth that permeates the whole thing. Yes. So that's how I see it. Actually, you know, I gave a talk about Pythagoras and Pythagoreans just a few weeks ago at the Commonwealth Club of California in San Francisco. And because of that, I did a kind of a deep dive into the subject. And I learned that I actually totally misunderstood Pythagoras and Pythagoreans, that they were much deeper than I thought. Because, you know, most of us remember Pythagoras from the Pythagoras theorem about the right triangles. We also know that Pythagoreans were instrumental in introducing the tuning system for the musical scale, the famous perfect fifth, three halves of the, for the G for the soul, compared to the frequency of, of Do or C, you know. And so, but actually they were much more interesting. So for them, numbers were not just clerical devices, you know, that kind of thing that you would use in accounting only. They were imbued with, with the divine. And I cannot, I cannot say that I, I think we lost it. At least I have lost it. I look at numbers and I don't really see that. The divine, the divine, that they clearly did. And so the, why else, you know, how else would you explain? In other words, divine is, of course, is a term which is, you know, it's a bit loaded. So it's hard to escape that. Let's just say something that more from the world of imagination and intuition than from the world of knowledge. Let's just put it this way. They were able to divine, okay, strike that to intuit, to intuit that the, the planets were not revolving. And the sun and the planets were not revolving around the earth. They were the first ones, at least in the Western culture, as far as I know. And in fact, Copernicus gave credit to Pythagoreans as being his predecessors. They did not quite have the, the Copernicus model with the sun in the middle. They had what they call the central fire in the middle. And all the planets and the sun were revolving around, around the central fire or earth. They called it earth. So, but still, what a departure from the dogma, from the knowledge of the era, that the earth was at the center. So how could they come up with this idea? The reason was, in my opinion, that for them, the, the most movement of celestial bodies was like music. In fact, we call it musical universalis or music of the spheres. For them, the universe was this infinite symphony in which every being, you know, humans, animals, as well as the earth and other celestial bodies were moving in harmony, like different notes of different instruments in the symphony. And so they applied the same reasoning to the, you know, the cosmological model as they applied to their model of music. And from that perspective, they could see things deeper than

their contemporaries. You see, so in other words, they saw mathematics as a tool, but that tool was not limited to itself. They always, they always knew that there is more. And they knew also that every, every pattern that you detect is finite, but the world is infinite. They actually accepted infinity. They believe that infinity is real. And if you discern a pattern, great, you can play with it and you can use that. It gives you a certain lens through which to see the world in a particular way, which could be beneficial for you to learn more and so on. But they never had the illusion that that was the final word, that they always knew that it's not the whole thing. So there is more. There are more sophisticated patterns that could be discovered using mathematics or otherwise. And I think that what happened was we kind of lost this other side of their teachings. We took their numbers and they were like, idea that you could use mathematics to discern patterns and to find regularities and to explain things about the world. We took that and we ran with it. And we kind of dropped the other idea that in fact, there is, there is another side to it, which is kind of, to us now, we say, oh, that's mystical. But what does it mean, mystical? If it is something that helps you to make great discoveries. And the interesting thing is that the people who are in touch with the mystical among us are often seen as mad. And many of them are,
most of them are. Well, but not all of them. We mentioned Neils Bohr and Newton and Albert Einstein.
So that's where the conundrum is. How do you find the balance between the two? So the point I'm trying to make, and you know, and this is what I feel,
you know, if you ask me what I find most important today, like what makes me excited and enthusiastic and passionate is this idea of balance. So, you know, Nietzsche had this book, wrote this book in the 19th century called the birth of tragedy. And he presented this theory, which I think is kind of very useful, of the two sides of a human. One that comes from God Apollo. And that's our left brain, so to speak, proverbial left brain. So it's everything has to do with, that has to do with logic and reason and analyzing, dissecting, conceptualizing. And the other side, which comes from God Dionysus, Dionysus. And that's responsible for intuition, imagination, love. Dionysus was also God of wine. So it's also that side of
human that makes us sing and engage in, you know, revelry and drink wine and spend time with friends
and love and enjoy it, you know. So Nietzsche advocated this point of view that those were two complementary sides of every human and as well as society. And the purpose of human life is to find balance between them. So math is both discovered and invented. We should be okay with having both ideas in our head and living the balance. But more importantly, for me,
Apollo is like math and Dionysus is like love. So Dionysus and Apollo in modern version is love and math. I returned to that question we had about GPT and the language models. And I think about this quite a lot, which is when the model and we know what is trained on, we know the parameters, when all the different hacks that are involved in the training process and the fine tuning process. And the final results, whether it's GPT five, six or seven, will result in hundreds of millions of people falling deeply in love with that language model and to be able to have conversations that are very much like the conversations we have with somebody we're deeply in love with. And not only that, the model will say that is deeply in love with us. And who are we to say it is not? I think it's the same imperative that you described in the scientific mind

that wants to throw away the subjective. That same imperative wants to throw away the feelings that AI might have. And I'm very careful to not ignore when an AI system says it's lonely, it's afraid, it doesn't want to die, it misses you, it loves you.
I'm with you. I would also say that you could, for instance, say that the origin of that is the romantic novels that were fed to it, for instance. However, then you can retort. But I consider my subjective unique feelings are also the reverberations of the novels I have read because I have learned or movies I have seen. Because that's the purpose of movies, or kind of to teach us how to express ourselves, how to feel, maybe even one could argue that. Some people have argued that. I agree that this is, there is no obvious answer to this. But see, that's exactly my point. That is an example of something which is paradoxical for which there is no answer. And that's where the subjective has an important role. For someone, that type of interaction would be helpful, would be consoling, would feel, would make them happy or sad or whatever, would kind of strike the nerve. For some, it won't. And I agree with you that, in principle, there is no one to judge this. This is where subjective is paramount. But remember, a lot of this has been anticipated by artists. The great movie, Her, there you have this guy who is this lonely, he kind of writes letters or something.
The romantic letters. For other people. But he doesn't have a partner. He's lonely. And then he gets this sort of enhanced version of Siri with the voice of Scarlett Johansson, which is very sexy voice, obviously she's a great actress. And then, at first, it looks like a fantastic arrangement. He confides in her, she tells him things, she makes him happy and so on. Until he finds out that she has a relationship, quote unquote, if you can call it that, with 10,000 other people.
Not two others, not three others.
Yeah, like 10,000.
Because it has a computing capability. So yes, definitely.
Oh, it certainly makes sense. It's a good explanation.
And the guy is heartbroken. But see, here's my analysis of this. It's like a couch therapist. Okay. The guy did not have the courage to go out in the real world and to meet a woman and to, you know, get a girlfriend and so on. It's true. No fault of his own, perhaps, because, you know, you may have had some experiences which made him withdrawn and closed and so on. And a lot of us are like this. You know, I had periods like that myself. Definitely can sympathize and relate. However, part of the joy of having this Siri-like relationship for him, one could say, was the absence of that fear that she would abandon him, which prevented him from initiating a relationship with a human being. And yet, it turns out that he could be betrayed, quote unquote. The chick would be unfaithful to him, quote unquote, anyway. So then that means that it did not resolve the underlying fear having that relationship. So in other words, that human element of the relationship still found its way into the seemingly sterilized, protected partnership. So the human being rears its head, anyway.
And I think the lesson there is that the system in the movie Her actually gave him a lesson that even AI could betray you, even AI can leave you, even AI can be unfaithful to you. And I would argue that the next AI he meets will be one he actually falls in deep love with, because he knows the possibility of betrayal is there, the possibility of death is there,

the possibility of infidelity is there, because we need that possibility to truly feel.
Or he would turn off his Siri program and get out of his house, go to a local bar,
and strike a conversation with a human being. Although you might say, by then,
some of those might be androids. And we don't even have a good test to know the
difference you just want or the other. And that was predicted by another great movie, right?
So there's Blade Runner. Blade Runner.
How interesting that artists could see that so long ago. Of course, Blade Runner was based on a
novel by Philip K. Dick, the androids dream of electric ship. That guy was a genius.
It's somehow that artists have their eyes open.
How is it that they anticipate? Is it also a large language model that they're using for that?
An even larger one.
I hesitate to dismiss the magic in large language models. A lot of the work I've done
is in robotics. And the robotics community generally doesn't notice the magic of feeling.
When I've been working a lot with quadrupeds recently, legged robots with four legs,
and the feelings I feel when I see, you know, I'm programming the thing, but when the thing
is excited to see me or shows with his physical movement that it's excited to see me,
I cannot dismiss the feeling I feel is not somehow fundamental to what it means to program robots.
And I don't want to dismiss that. Please don't, please don't.
The robotics community often does engender robots. They really try to work hard to not
anthropomorphize the robots, which is good for technical development of how to do control,
how to do perception. But when the final thing is alive and moving, and it does whatever, like
I've been doing a lot of butt wiggling, it can wiggle his body, it can turn around and look up
excited. That's not just I know how it's programmed, but the feeling I feel, that's something. That's,
I don't know what that is. I agree. I agree with you. I hear you when you speak about it,
you speak with passion. And that's, for me, that is proof that it is magical, you see.
So don't, I would say, don't dismiss that, don't discard that. On the contrary, I think magic is
everywhere, you know. So I used to be, okay, kind of confession, okay.
Yeah, you already get confessed to quite a few addictions.
Yeah, I'm kind of, yes, I'm kind of worried.
Recovery, recovering for many.
But you know, I, in old days, I was more on the side of everything is computational,
or everything can be explained by science and whatever, you know, that I would dismiss and
disregard, you know, the intuitive or imaginative things. So then I had a flip that suddenly I
started feeling it and started seeing it and so on. But so then the pendulums had swung in the
opposite direction. Then I was arguing that, you know, somehow that was the real, that imagination
was intuitive, imaginative was real, and discounting what you just described. And I would argue with
people saying, no, no, this, you know, this is not real, this is all, you know, imitation game and so
on. But you see that what's new now, the new Edward, okay, is the 2.0, 3.0, is the one who is
seeking balance, who is not, who is, because suddenly become aware that no matter which one
sided, lopsided point of view you take, you're limiting yourself. So whereas even a couple of
years ago, you know, if you just told, you told me what you just described, I would be like,
you know, being polite, I would just, I wouldn't contradict you since you're the host anyway,
right? It's not a law. So, but I would be like, uh-huh, uh-huh, but I wouldn't say anything.

But suddenly I find this moving, I find it moving, I honest, I'm not being facetious. I find it moving, and I almost feel like I can see it through your eyes, because the way you describe so vividly, and you're passionate about it, and this is what's real. So ultimately, love is not, is neither in language models, nor in something mystical. It's exactly in these moments of passion, of passion. And I would, I would, I would even go as far as saying that in this moment when you're describing it, it, there was a connection of sorts so that I could feel your passion for it. And in this moment, something else comes up, which is far beyond any, any theories that we can come up with. And that's what we, for now, exactly. So on the one side, there is this impulse of finding the theory, a theory, and then there is another impulse to escape from what has already been known. So one, in other words, like in my basic example is one impulse to say everything is real numbers, square root of negative one doesn't exist, but another impulse is I'm going to be this naughty child who is not afraid to be an idiot, and I will say square root of negative 15 is real. And both are essential when it's done with conviction, when it's done with passion, when it's not like, you know, meh, you know, gratuitous, or when it's not, it doesn't come from self limit, self limiting, but comes from this sense of this is how I am. This is how I feel. It is real. That's where progress is. That's where creativity is. And that's where I would even say a real connection is, because the strife to me that we I observed today in our society and the society level at the level of humans and so on, it comes from not seeing the other person actually and being caught up in a very specific conceptual bubble, you see, and the way out of it is not to refine the bubble, but just break out of it. A good guide out of the bubble is a childlike passion. We're discovering that and following it. Goosebumps. Yeah. Following the goose bumps. To the, you know, not the rigor of science, but the magic of goose bumps. Then try to, and then if you're interested, try to find a confirmation of those goose bumps in science or whatever, you know, you find interesting. And most of the time you'll fail. And most time you fail, which we also love because then it sets us up for that moment of bliss when we succeed, right? Exactly. Quick pause. Bath and break. You mentioned Gato's the completeness theorem. Can you, can you talk a little bit about it? What is it as you understand it? Did it break mathematics? Maybe another question is, what are the limits of mathematics? What is mathematics from the perspective of gayness and completeness theorem? Oh, yes. How much time do you have? We talked about time previously. Time was an illusion, right? So we agreed.
So Kurt Gödel was a great Austrian mathematician and logician. He moved to the United States before Second World War and worked at the Institute for Advanced Study in Princeton, where he was a colleague of Einstein and other great scientists, von Neumann, Hermann Weil, and so on. But, you know, one interesting quote that I like in this regard is that Einstein said that at some point he said that the only reason he came to the Institute was that he would have the privilege of walking back home with Gödel in the evening. So in other words, Einstein thought that Gödel was the smart one, okay? So his most important contribution was his two incompleteness theorems, the first incompleteness theorem and the second incompleteness theorem. And what is this about? It's really about limitations, inherent limitations of mathematical reasoning, way of producing mathematical theorems, the way we do it. So to set the stage, how do we actually do mathematics? So we know that we discussed that say physics is based on mathematics and you could say chemistry is based on physics, biology is based on chemistry. Okay, so it comes to mathematics. What is mathematics based on?

Well, mathematics is based on axioms. So any field of mathematics can be presented as what is called the formal system. And at the core of the formal system is a system of axioms or postulates. These are the statements which are taken for granted.
Given without proof? Without proof. An example would be, so one of the very first formal systems was the system was Euclidean Geometry developed by Euclid in his famous book Elements about 2200 years ago. And it's about, well, it's a subject familiar from school because we studied, but what it's really about is about the geometry of the plane. And by plane, I mean just the stable top extended to infinity no directions, kind of a perfect plane, a perfect, perfectly even table. And so Euclidean Geometry is about very geometric figures on the plane, specifically lines, triangles, circles, things like that. So what's an example of an axiom? An example of an axiom is that if you have two points, which are not, which are distinct, two points on the plane, then there is a unique line which passes through them. No, it kind of sounds reasonable. But this is an example of an axiom. In mathematics, you have to have a seed, so to speak. You have to start with something. And you have to choose certain postulates or statements, which you simply take for granted, which do not require proof. Usually, they are ones which kind of intuitively clear to you. But in any case, you cannot have any mathematics without choosing those axioms.
And you refer to those as the observer because they're kind of subjective.
The observer comes in the process of choosing the axioms. Who chooses the axioms?
The turtles that it's all sitting on top of.
As Alan wants to say, who is watching the watchers?
Yeah. And so in mathematics, what you see, mathematicians are so clever. It's really kind of like a little kind of a game of mirrors that we often like to say, and I used to say that, that mathematics is objective. It's really the only objective science. But that's because we hide this fact that actually is based on axioms. And the fact that there is no unique choice, that there are many choices. And so Euclidean geometry is actually a good illustration of this because Euclide had five axioms. Four of them were kind of obvious, like the one I just mentioned. And the fifth, which came to be known famously as a fifth postulate, was that if you have a line and you have a point outside of this line, there is a unique line passing through that point, which is parallel to the first line, meaning that doesn't intersect it.
And Euclide himself was uncomfortable about this because he felt that it was kind of, you know, that he takes for granted something that is not obvious. And for many centuries after that, mathematicians were trying to derive this axiom from other axioms, which were more obvious in some sense, and they failed. And it was only almost 2000 years later that mathematicians realized that you can't, not only you cannot derive, but you can actually replace it with its opposite. And you will still get a bona fide consistent, not self-contradictory, which is called non-Euclidean geometry, which of course sounds very complicated, but it's not. Think of a sphere,
just the surface of a basketball or the surface of the earth, you know, idealized.
The analogs, so you have points, you have analogs of lines, which are meridians, right? Every two meridians intersect, unlike parallel lines on a flat space. There is also so-called hyperbolic plane, where there are infinitely many lines which do not intersect.
So every possibility can be realized, there are different flavors. This is a good illustration of what a formal system is. You start with a set of axioms, those statements you take for granted,

and this is where you have a choice. And by making different choices, you actually create different mathematics. After that, there are rules of inference, logical rules such as if A is true and A applies B, then B is true. Most of them were actually introduced already by Aristotle, even before Euclid. And then it runs as follows. You have the axioms, which are accepted as true statements. Then you have a way to produce new statements by using the rules of logical inference from the axioms. Every statement you obtain, you call a theorem, and you kind of add it to the collection of true statements. And then the question is, how far can you go? How many statements can
you prove this way? Of course, you want the system to be non-trivial in the sense that you don't prove everything. Because if you prove everything, it would mean that it's self-contradictory, that you prove a statement A and its negation. So that's kind of useless. It has to be discriminating enough so that it doesn't prove contradictory statements. So there is already a question of that mathematician's consistency. It has to be consistent in the sense that it is not self-contradictory. And then the idea that was basically prevalent in the world of mathematics by the beginning of the 20th century was that, in principle, all of mathematics could be derived this way. We just have to find the correct system of axioms. And then everything you ever need could be produced by this procedure, which is a really algorithmic procedure, which actually could be run on a computer. Now, think about it. What is special about this process? In this process, you are just manipulating symbols, basically. You're going from one statement to another without really understanding the meaning of it. So it's an ideal playground for a computer program. It's a purely syntactic process, where there are some rules, some rigid rules of passing from one statement to the next. Most mathematicians believed that this way, you can produce all true statements. And if this were true, it would give a lot of credibility to the thesis that everything in life is computational, or life is computation. Because then, at least mathematics is computational, because then it can be programmed. And a computer, after sufficient time, depending on its capacity, would produce every true statement.

So Gödel's first incompleteness theorem says that that's not the case. And it not just says it, but it proves it at the highest level of rigor that is available in mathematics. That is to say, within another formal system that he was operating in. So more precisely, what he proved was that if you have a sufficiently sophisticated formal system, that is to say that you can talk about numbers, whole numbers in it, that you have whole numbers, one, two, three, four, you have formalized the operation of addition and multiplication within the system.

If it is consistent, that is to say, if it's not completely useless, then there will be true statement in it, which cannot be derived by this linear syntactic process of proving theorems from axioms. It's really incredible. So this was a revolution, 1931, a revolution in logic, a revolution in mathematics, and we're still feeling the tremors of this discovery.

In the similar time, the computer is being born, the actual engineering of the computational system is being born, which is ironic. Turing was Alan Turing, who was considered as the father of modern computing. So he actually did something very similar. So he had this halting problem, he proved that halting problem cannot be solved algorithmically, that you cannot, out of all computer programs, roughly speaking, you cannot have an algorithm of choosing out of

all possible computer programs, which ones are meaningful, which ones will not, which ones will halt. Very depressing results all across the table. Or on the contrary, life affirming, depends on your point of view. Because everything is full of paradoxes.
So that means, so you're right, it's depressing if we are sold on a certain idea from the outset, and then suddenly this doesn't pan out. But okay, so which I retort. What if, what if he proved that actually, you know, everything can be proved. So then what, what is left to do if you're a mathematician? So that would be depressing to me. And here there is an opportunity to do something new, to discover something new, which maybe a computer will not be able to. Again, with a caveat, according to our current understanding, maybe some new technology, some new ideas will be brought into the subject. And the meaning of the word computation, like now we think of computation, a particular framework, tuning machines or church thesis and stuff like that. But what if in the future, another genius like Alan Turing will come and propose something else, the theory will evolve the way, you know, we went from Newton's gravity to Einstein's gravity. Maybe in the framework of that concept, some other things will become possible.
You know, so it's not, to me, it's kind of like not so much about deciding once and for all how it is or how it should be, but kind of like accepting it as an open-ended process. I think that's much more valuable in some sense than deciding things one way or another, you know. I wonder, I don't know if you think or know much about cellular automata and the idea of emergence. I often return to game of life and just look at the thing. Amazing, right? And wonder the kind of things they can do with such a small, you know, tools. From simple rules, a distributed system can create complex behavior. And it makes you wonder that maybe the thing we call computation is simple at the base layer, but when you start looking at greater and greater layers of abstraction, you zoom out with blurry vision. Maybe after a few drinks, you start to see some, something that's much, much, much more complicated and interesting and beautiful than the original
rules that our scientific intuition says cannot possibly produce complexity and beauty. I don't know. I don't know if anyone has a good answer, a good model of why stuff emerges, why complexity emerges from a lot of simple things. It's a why question, I suppose. But every why question will eventually have a rigorous answer. Not necessarily. We could have an approximate answer, which still eludes something. Like quantum mechanics. 99% maybe. We'll be able to describe it with 99% certainty or 99% accuracy. And then maybe in 100 years or next year, somebody will come up with a different point of view, which suddenly will change our perspective. To this point, I want to say also one thing that I find fascinating, speaking of paradoxes and so on. Do you remember how everybody was freaking out about this blue dress and blue? Was it blue or was it black? Was it yellow? I think yellow or white or black and blue. It almost broke Twitter, you remember that night. So there are many examples like that where you can perceive things differently. And there is no way of saying which is correct and which is not. For instance, you got this, the bars, the Rubens bars, you know, where you have, from one perspective, it's a vase. From another perspective, it's two faces. Then there is this dark rabbit picture, where you can Google it. If somebody doesn't know, they can Google it and find it. It's very easy. Actually, Ludwig Wittgenstein devoted several pages, dark rabbit, in his book. And so there are many others. There are like squares where you can see, a square, you can see from different perspectives this way, that way, and so on. So when we talk about neural networks, we're talking

about training data and stuff. And so that you have some pictures, for example, that you feed to your program, and you try to find the most optimal neural network, which would be able to decide which one is it, the dog or a cat or whatever. But sometimes it doesn't have a definite answer. So what do you do then? So actually, as a question, I actually don't know, has modern AI even come to
appreciate this question, that actually sometimes you can have a picture on which you cannot say what it is in it. From one perspective, it's a rabbit. From the other perspective, it's a duck. How are you supposed to train? If you have a neural network, which is supposed to discriminate between, distinguish between ducks and rabbits, how is it going to process this, you see? Well, so the trivial trick it does is to say there's this X probability that it's a duck and this probability that it's a rabbit. That's a good approach. But also I would say there is no like given percentages. For instance, actually, at some point, I was really curious about it. And I looked and for some, for each picture of this nature, and there are a bunch of them you can easily find online, my mind immediately interprets it in a particular way. But because I know that other people have could see it differently, I would then strain my mind and strain my eyes and stare at it and try to see it in a different way. And sometimes I could see it right away. And then I could go back and forth between the two. And sometimes it took me a while for some pictures. So in that sense, even if these probabilities exist, they are subjective.
Some people immediately see it this way, some people may see it that way. And I think that nobody knows, not psychologists, not neuroscientists, not philosophers, what to make of it. The best answer, of course, is a scientific mind. Even though I say, no, don't look for interpretation, leave some place for mysticism or mystery, right? I say that. But of course, I want the theory, I want an explanation. So the best explanation I find is from Niels Bohr's Complementarity Principle. So it is like particle and wave, that there are different ways to look at it. And when you look at it in a particular way, another side will be obscured. Think about it like the other side of the moon, you know? So like, we are observing the moon from one side, and then we don't see the other side. There is a complementary perspective where we see the other side, but not the side we normally see. But the moon is the same, it's still there. It's our limitations of being able to grasp the whole. That's Complementarity. And we know that from quantum mechanics that our physical reality is like that, rather than being certain, rather than being one way or another.
And we should just, as a small aside, in terms of neural networks, mention that at the end of the day, there's humans. It's built on top of humans. Or with chat GPT, that it's using reinforcement learning by human feedback. We're actually using a set of humans to teach the networks. And that's the thing that people don't often talk about, because or I sometimes think about that those humans all have a life story. Each human that annotated data that fed data to the network, or did the RLHF, they have a life story. They grew up, they have biases. There are some things that they like, there are some things they don't like, which kind of appear under the radar screen. They may not be aware that they are exercising those biases. That's the point. What you brought up is a very important issue here. Not so much issue, but it's not a bug. It's a feature, in my opinion, that implicit in the discussion of the question is thinking computational and so on. It's the idea that our conscious awareness covers everything within our psyche. And we just know that that's not the case.

We have, all of us have observed other people who have had sort of destructive tendencies. So, obviously, they did things destructive for themselves. And many of us have observed ourselves to doing that as part of human nature, right? So, and there is great research in analytics psychology and, you know, in the past 100 years, strongly suggesting, if not proving, the existence of what Carl Jung called the personal unconscious and also collective unconscious, this kind of a circle of ideas, which are under the radar screen, which lead us to some strong emotions and inspire us to act in certain ways, even if we cannot really understand. So, if we accept that, then the proposition that somehow everything can still be covered by our actions, which are totally kind of neutral and totally righteous and totally conscious, that it becomes really tennis. Let me ask you some tricky questions in terms of how big they are.
In terms of how, you know, they become difficult because of how much of a romantic you are. What do you, is the most beautiful idea in mathematics? Another one we can ask is, what is the most beautiful equation in mathematics?
Well, I may have just broken your brain because what your brain is doing is walking down a long memory lane of beautiful experiences. Well, you see, in mathematics, we have this idea that we have an idea of a set, right? So we have a collection of things, for instance, you know, the set of tables, the set of chairs, and so on, or set of microphones, but could be set of numbers, could be set of ideas, could be a set of formulas, mathematical equations. And then we have the notion
of an ordered set, ordered, like the set in which there is order, which means that for every two members of the set, we will say which one is better than the other or greater than the other. For instance, all numbers are ordered, five is greater than three, five is less than seven, and so on. But not all sets are ordered. So the set of beautiful theorems is not what beautiful equations is not ordered. So in other words, there are many best equations.
And so Richard Feynman chose one, which I think one of the best, is that if you take E, the base of natural logarithm to the power pi i, so you have pi, you have E in it, the base of natural logarithm, you have pi i, which is square root of negative one, then the result is negative one. So that's up there, for sure, in the pantheon of beautiful formulas, you know, that every, I think pretty much every mathematician would agree. I don't know what my favorite one is.
I'm just lingering on that one, Euler's identity. What makes it beautiful? Just a few symbols together. I mean, part of it is actually just trying to define what is beautiful about mathematics.
And that is laid in there in this particular equation that is somehow revealed when the human eye looks at it. Why is it beautiful, do you think? Pi i.
There is an element of surprise in it. How is it possible? We always think of pi as the ratio between the circumference of a circle and its diameter. Here, we are taking some number to the power pi, not even pi, mind you, but pi multiplied by square root of negative one.
Surely, this is something completely incomprehensible. And yet, the result is negative one, you see? And if you take E to the power two pi i, you get one, actually one.
So I would guess that that's, but in other words, the initial reaction is just that of a surprise, I guess. I guess for anyone who first comes across.
That these three folks, four folks got together. It reminds me of the idea that Hitler, Stalin, Trotsky, and Freud were all in Vienna in some early, at the beginning of the 20th century.
And Biggestine was the classmate of Hitler, you know this?

I did not know this, no. So it makes you, you know, you can imagine a situation where they're all sitting at a bar together at some point, not knowing it, but they somehow, it all made sense in space-time to be located there. And that's what this feels like, some kind of intersection.
Intersection, yes. But I would say that after the initial shock, you look at the proof of this equation. And it actually does make sense. And actually, it is nothing but the statement that the circumference of the circle is. And in fact, in this case, the circumference of a semicircle is equal to pi. And that's where it comes from.
In the end, the truth is simple.
In the end, the truth is simple. Not necessarily easy, but simple.
So I mentioned to you offline that I, desperately in trying to figure out the optimal in an order set questions to ask you, texted Eric Weinstein asking for what questions he can ask you. And he said that you are definitively one of the greatest living mathematicians, so don't screw this up. But he did give me a few questions. So he asked to ask you, what are the most shockingly passionate, this is in Eric's language, what are the most shockingly passionate mathematical structures? And he gave a list of four for him, but he said he really wanted your list. Okay, let me say that shockingly passionate mathematical structures. Shocking. Is there something you can, is there something that jumps to mind?
Sure. I'm here to shock. So first of all, Eric Weinstein is a very dear friend, I have to say. And I really, really, really appreciate and love him. He's just like my brother. So, you know, it's interesting to have a question posed by him.
It may be if we can linger for a moment, what do you think is special about Eric Weinstein for what you know of his work and his mind? The way he sort of straddles so many different disciplines. It's like a Renaissance man. There are very few people like that at any given moment, let alone the 21st century, where information has become so, you know, huge that it's almost physically impossible to be able to keep track of things. And yet he does, and he has his own unique vision and unique point of view, and he has integrity, which is like almost impossible. Like I can't think of so many people who possess that, those qualities, almost no one.
And also the ability, in some sense, to embody the balance that you talked about, of both the rigor of mathematics and the imagination. Humanity also, I would say, you know, like we talk about imagination as a kind of a counterpoint to knowledge or logic. But just basic humanity, you know, just basic compassion, just being able to, because every destructive, I would say, like every destructive society, you know, like be it Germany, you know, under Hitler or Soviet Union under Stalin and so on, was based on some kind of what was considered unassailable truths. So it kind of conceptual system, you know, if you think about it, right? There is a beautiful episode of this series by Jacob Bronowski, you know, where he talks about, he filmed it in Auschwitz, talking about the certainty that what led the Nazis to killing people wholesale was a certain, it was almost a mathematical idea. And they just basically bought into this idea and checked out their humanity at the door. So I would say that antidote to this type of thing is not necessarily even imagination in a kind of elevated sense that we have been discussing today, that is exemplified by our greatest scientists and philosophers. But just basic humanity, you know, basic human, basic common sense of just like knowing that it's just not right. And I don't care what my, what my ideology tells me, but I'm just not going to do it. So that I think is kind of missing a

little bit in today's society, because people get a lot too caught up in, in the ideology, in certain conceptual frameworks. So societies that lose that basic human compassion, that basic humanity around the trouble. Oh, very much so. But not only society, like a human being. And Eric is one of the people I agree with you, keeps that flame of, like, I trust that he will not do something that's not human. That's not right. I just feel that, you know, like there's some, some people you just kind of feel that they won't cross that line. And that's a huge thing, you know, today, because I have to say, looking back, definitely, I have not heard people personally, but like, I could be mean, for instance, I could be harsh. And now I see it as a sign of weakness, as a sign of insecurity. You know, I saw, I saw your interview with Ray Kurzweil the other day. Beautiful. I was really moved by it. But, you know, at some point I was like, I looked at him at this sort of like Dr. Evil. I'm kind of ashamed of it now, but like, you know, I'm kind of coming clean. And I would, you know, because, well, why? Because I needed an adverse adversary in my mind, because I projected onto him kind of the fears that I had that we will be, the AI will conquer us and so on. And this was rooted in my kind of awakening moment in a sense, a kind of a moment where I suddenly started to see the other side. So, but I wasn't sure yet. You see, you had to feel it. So I had to have a fight about it.
Yeah, you had to actually have the projection. I had to. So it was not in, I believe that it was not in me already. So I had to throw it onto somebody. Yeah. And that's not balance yet. So balance is when you recognize that it's you, actually. So, and I had this moment, actually, it was so amazing. Like, I would give this mean, I would talk about AI and the dangers, and he would always be my, like, foil, you know, I would put like a sinister photograph of him on the slide. And I was like, look at this guy. He wants to put nanobots into your brain. And he's also like high and high, a top executive at Google and so on. Like, so I would create this whole narrative. And then something happened where I was giving a lecture, this is 2015, at the in, in Aspen, Aspen Ideas Festival, which is a wonderful festival, the keynote speech, actually. And I, and I was doing my usual stick. And then suddenly I said, I came up to that, there was a big screen. And there was a picture of him there. And I came up to the screen and I kind of touched it with my hand. And I said, but I don't want to pick on Mr. Kusar because he's me. I had this revelation that I'm actually fighting with myself, with my own fears. And, and then I learned about his, his, his father, his father died when he was young. And that he is, in fact, he's very, to his credit, he's very sincere, an upfront about it, self disclosure, I think it's very essential, by the way, in all this discussion, like, what really motivates you? He said it, he said it publicly many times, even as early as 2015, I could find this information that he wanted to reunite with his father in the cloud. And suddenly I saw him not as a caricature that exemplified all my fears, but as a human being who, a child longing for his father, grieving for his father. So suddenly it became a story of love story. And, you know, so that is, so in other words, I've seen it in myself, this capacity to project my own fears, and then fight with other people over something that actually was my own. And as soon as I got to this point of seeing him, and then my next lecture, actually, I talked about it, about him in this way. And I, and I said, look, you know, it's a love story. And he is actually, it's not how I would want to reunite with my father. But like you said, you know, that if I am consistent, I have to allow the possibility that different people perceive things differently. And so for him, that's his imagination.

So, you know how, who is this Voltaire, I think, is ascribed to Voltaire. It's like, I disagree with you, but I will fight to death for you to have the right to say it. So now that I feel like my position is more like, I disagree with him, that this is the way to approach death and to approach the death of loved ones and how we miss them and how we, you know, that sense of loneliness and inability to interact directly. That's not something that it is nice with me. But I think it's also, it can also be called imagination from his perspective and look motivated by that, how much he has brought, how many interesting inventions, like his musical inventions, for instance, naturally, because his father was a composer, music composer and a conductor. So in other words, from a bigger scheme of things, even if I think he's misguided,
still, I can't deny that it's certainly a leap of faith from his perspective to try to say that this is the way we can all connect to our loved ones. And because it is sincere, and I see it now as sincere. And in fact, in your interview, you really teased it out of him. And I was really moved by it, I have to say. It's like, he has a little bit of a melody. It was really, really sweet when he talked about his father. And I can relate to, you know, my father died four years ago. And I can relate what a heartbreak, I was much older than Ray was when his father died. But I can relate to this, to this longing and that grief, you know, and when he is somebody sincere, and he puts his, opens his cards and, you know, and says, this is why that's what I want to do it, because I want to recreate my father and want to be able to talk to him this way. Then we have a serious, then we understand, you know, the opposite of it would be not this closing. And just pretending that this is how it's supposed to be in a scientific term, so it was replacing the real emotion that comes from the heart by some kind of a theory which comes from the mind. And this is where we can go astray, because then we get become captives of frameworks and conceptual systems, which may not be beneficial to our society.
In tough times, we need the people that have not lost their way in the ideologies. We need the people who are still in touch with their heart. And you mentioned this with Eric, it's certainly true. I disagree with him on a lot of stuff. But I feel like when the world is burning down, Eric is one of the people that's you can still count on to have a heart. We've talked a lot over the past year about the war in Ukraine and the possibility of nuclear war. And it feels like he's one of the people I would call first, if God forbid, something like a nuclear war began, because you look for people with a heart, no matter their ideas.
And that's right. It takes courage and it takes a certain self-awareness, I would say. And which brings me, you know, I think the crucial is that which was inscribed, you know, on the temple of Apollo and Delphi. It was a statement, know thyself, know yourself, you know, like, who am I? Ultimately, it goes down to this and all these debates. And the point is that I was like, I used to be, like I said, you know, pessimistic at some point, and I was scared even of where development of AI was going. This is about 2014, 2015.
And now I'm much more, so for instance, after I saw Ray Kurzweil as a human being, after I could relate to him and sympathize with him, suddenly I stopped seeing him in the news. Like before that, I would always see him in the news saying, we're going to put nanobots in your brain by the year 2030, whatever, you know, and then we upload you to the 21st. And I would be like, no, you know, the story was terrible. Suddenly I didn't see him anymore. I had to, you know, so now it makes me question, who was creating the trouble?

What was all within you? Was it him who was creating the story and the trouble? Or was it my mind? You see? And so as I become, as I became self aware, suddenly other possibilities opened. And suddenly that conflict, which by the way, if I kept giving this nasty, you know, talks about him one day, I suppose we would have a debate. And so you have this one person stays there. And what I learned is that it's a never ending conflict. This conflict just does not end. But there is an alternative. There is a better way, which is to realize that it is you arguing with yourself. Now, if you want to continue arguing with yourself, continue as long as you need. Just be careful not to destroy too many things, you know, in the process. But there is an option of actually dropping it, of actually dropping it. This is so, I was so surprised by this. Yeah, it's discovering in yourself the capacity, the human capacity for compassion. And you understand that he has a perspective, he is operating in the space of imagination, the human being like you. And we're all in this kind of together trying to do this. Both, ultimately. And also it's like, with realizing how much I have screwed up, you know, comes this humility also. So like, I find it extremely hard now to like really lash out at somebody and to say like, you're horrible or whatever. Because immediately the question is, who am I to criticize, you know? So is there another way to have a dialogue? Is there a way to, you know, speaking, you know, since we talked about the innocence of a child and how much it drives a discovery in science and so on, you know, I remember, I think I heard of Adyashanti who gave this nice example. He's like, when you're a kid, you know, you go and you play with your friends and then you fight with another kid. And he was like, I hate you. I don't want to see you again. And you just go home like after half an hour, okay, what are you going to do? You want to play? So you come out, it's like, hey, you want to play? You don't talk about what happened, you don't rehash this, you know, just keep going. And sometimes I think we are on the verge, maybe, of learning that. Because I think that if we are, if we continue to push each of us, our set of ideas and like ideologies and like, you know, what matters to us and so on, like, yeah, no, no, what matters to you. But like, there are other ways to approach other people, there are other ways you can find point of contact. Speaking of which, mathematics, mathematics, Michael formulas are universal, represent universal knowledge. Two plus two is four, whether you vote for this guy or that guy in the election, you know, how about that as a point of contact of commonality, you know, and nobody can patent those formulas. Did you know that? And there is a Supreme Court decision that mathematical formulas cannot be patented like Einstein could not patent equal equals MC squared. It doesn't belong to him because if the formula is
correct, then it belongs to everyone. So what do you think of that all too tricky question? And if you want, I can deeply bias your answer by giving the list of four that Eric provided. Oh, no, let me give my mind. I cannot see, by the way, what you have. But I can guess some of them. So I'm going to try to do something different from him. So I already mentioned one, which is that you have one dimensional numerical system, which is real numbers, you have two dimensional, which
is complex numbers, you have four dimensional, and it's kind of it's probably connected to what he wrote because has to do with some homotopy groups of spheres and stuff like that. Then, of course, one I love, okay, one plus two plus three plus four plus five plus six and so on. Does it make any sense, the sum? You probably heard about this one. It became very popular at

some
point. One plus two plus three, I did a video for a number file, the YouTube channel about it maybe 10 years ago. So one plus two plus three plus four plus five, ostensibly diverges, goes to infinity, because you get a bigger and bigger number. And yet there is a way to make sense of it in which it comes up to minus one over 12. How fascinating. First of all, the answer is not even a positive number, and it's not an integer, it's not a whole number, it's minus one over 12. So sometimes people ask me, what is your favorite number? And it's a kind of a joke. I say minus one over 12. It's actually 42. So your favorite number is not in order to set. Right. So what else? What else? So language program, of course, I have to mention that. And we'll explore that in depth. Do you want, do you want to know what Eric said? Sure. Sphere version, boys surface hop vibration, hop vibration, okay. And Pi one of SL three. Okay. Oh, yes. So that's the, that's the famous cup trick, you know. Okay, look, so this is how it works. No tricks. No tricks. No magic. Honest. It is magical. Okay. But not because I'm tricking you. So you start with a bottle like this or a cup, and you start twisting it. And at the same time, you twist your, your arm. Then you come. So this is actually going to rotate at 360 degrees, the full turn. Then you say, okay, I'm going, I won't be able to do another turn because then my arm would really get twisted. I'll have to go see a dog yet. If I do it second time, it untwists. This is the Pi one of SL three Eric is talking about. Yes. So there is something where the first motion is not trivial, but if you double down on it, you come back to the initial position. It's a very closely connected to the fact that we have elementary particles of two types bosons and fermions. So bosons are, for example, photons or carriers of other forces or the Higgs boson. It is called a boson for a reason because it is a boson in honor of Indian mathematician Bose, B O S E and Einstein. So these particles obey what's called Bose Einstein statistics. But then there are other particles called fermions in honor of Enrico Fermi, Italian born mathematician who worked in the US. And they follow what's called Dirac Fermi statistics. And those are electrons and constituents of matter, electrons, protons, neutrons and so on. And they have a certain duplicity, if you will. And that duplicity is rooted mathematically in this experiment, this little experiment that they have just done. So I can, I imagine, speaking of imagination, okay, so I'm just kind of riffing on this. Imagine a world in which this will not be shocking or like, in this case, it's not even shocking because I haven't really explained the details because I can't do it in two minutes. I indicated what this is all about and so on. But imagine a world in which this is not foreign to most people that most people have seen it before or they're not afraid to approach this type of questions. Because, you know, we talked a little bit about math education, but I really believe that a lot of people in our society, and it is not only in the United States, but throughout the world, a lot of people have been traumatized. It's really PTSD. That's why people, when they see a mathematical formula or like, even like, how they need to calculate tip on the bill, they just, they're terrified because it brings up those memories when they were kids and being called to Blackboard and solve a problem. You can't solve a problem. An unscrupulous teacher says, you're an idiot. Sit down and you feel ashamed and, and, and, you know, lonely and that stays with you. And so I think that unfortunately that's where we are. But I, but one could dream. And so my dream is that one day we'll be able to overcome this. And actually, all of these treasures of mathematics will become widely, widely available, or at least people will know where

to find them. And they will not be afraid of going there and looking. And I think this will help because like I said, for one thing, it gives you a sense of belonging. It gives you, it kind of is an antidote to the kind of alienation and separation that we feel today, oftentimes, because of ideological divide, sectarian strife and all kinds of things like that. Because then you will, once you see, there's a critical mass of this beauty that kind of like dawns on you, is like, my God, this is what we all have in common.
You mentioned Langlin's program. We have to talk about it.
Sure.
At the core of your book and your work is the Langlin's program. Can you describe what it is?
Sure. So Langlin's is a mathematician. It's a name of a mathematician, Robert Langlin's. Canadian born, still alive. He was a professor at the Institute for Advanced Study that we talked about where Einstein and Gödel and other great scientists have worked. In fact, he used to occupy the office of Albert Einstein at the Institute for Advanced Study. So he, in the late sixties, he came up with a set of ideas which captivated a lot of mathematicians, several generations of mathematicians by now, which came to be known as the Langlin's program. And what it is about is connecting different fields of mathematics, which seem to be far away from each other. For example, number theory, which, as the name suggests, deals with numbers and various equations with x squared
plus y squared equals one. And on the other side, harmonic analysis, something that any music lover can appreciate because the sound of a symphony can be kind of decomposed into sounds of different instruments. And each of those sounds can be represented by a wave, like this, like a sine function. Those are the harmonics. The period of a harmonic periods of different notes are different. They correspond to different notes and different instruments, different semitones, if you will. But they all combine together into something special, which cannot be reduced to any one of those. So mathematically, it's the idea that you can decompose a signal into, as a collection, as a simultaneous oscillation of several elementary signals. That's called harmonic analysis. So what Langlin's found is that some really difficult questions in number theory can be translated into much more easily tractable questions in harmonic analysis. That was his initial idea. But what happened next surprised everybody, that the kind of patterns that he was able to observe, the kind of regularities that he was able to observe, which were quite surprising, were subsequently found in other areas of mathematics, for example, in geometry, and eventually in quantum physics. So in fact, Ed Whitton, who is kind of a dean of modern theoretical physicists, Professor at the Institute for Advanced Study as well, got interested in this subject. I described in my book how it happened. And he was instrumental in bridging the gap between these patterns in quantum physics and in geometry, finding kind of a substratum, a kind of a super stratum, if you will, or a kind of a way to connect these two things, kind of a bridge between these two fields. So subsequently, I collaborate with Whitton on this, and this has been one of the major themes of my research. It's sort of, I always found it interesting to connect things, to unite things. When I was younger, I couldn't, I couldn't understand why, but I was always interested in not in working in a specific field, but kind of cutting across fields. And then I would discover that, for instance, I talked to some people who know what happens in this field, but don't know what happens in the other field, or conversely. And then I would find it imperative to go out and explain to them, to the different sides

what this is all about, so that more people are aware of this hidden structure, so this hidden parallels, if you will. So that has been sort of a theme in my research. And so I guess now I kind of understand more why it's kind of a balance, like what we talked about earlier.
So can you elucidate a little bit how, what are the mathematical tools that allow you to connect these different continents of mathematics? Is there something you can convert into words that Languages was able to find, and you were able to explore further?
I would say what it suggests is that there is some hidden principles, which we still don't understand. My view is that we still don't know why, that we can prove some instances of these correspondences and connections. But we still don't know the real underlying reasons, which means that there is a certain layer beneath the surface that we see now.
So the way I see it now is like this, that there is something three-dimensional like this bottle, but what we are seeing is this projection onto the table and the projection to a wall. And then we can map things from one projection to another, and they say, oh my god, that's incredible.
But the real explanation is that both of them are projections of the same thing, and that we haven't found yet. But that's what I want to find. So that's what motivates me, I would say. From number theory to geometry to quantum physics.
So there is this one thing which has different projections, except it's not just the table and the wall, but there are like many different walls, if you will.
So what is the philosophical implication that there is commonalities like that across these very disparate fields? It means that what we believe are the fundamental elements of mathematics, are not fundamental. There is something beyond. It's like we previously thought that atoms were indivisible. Then we found out that there is a nucleus and electrons, and the nucleus consists of protons and neutrons. Then we thought, okay, protons and neutrons must be elementary. Now we know they consist of quarks. So it's about kind of finding the quarks of mathematics. Of course, beyond that, there may be even more. Which was my initial motivation to study mathematics, by the way, right? Quarks was the first time you fell in love with understanding
the nature of reality. What was it like working with Ed Whitten, who many people say is one of the smartest humans in history, or at least mathematical physicists in history?
Yes. Fascinating. I enjoyed it very much. I also felt that I have to keep up, you know.
So we wrote this long paper in 2007, and we collaborated for about a year. I have known him before, and we talked before, and I've seen him since. But it's very different to just meet somebody at conferences and have a conversation, as opposed to actually working on a project together. So he's very, very serious, very focused. This is one thing which I have to say. I was really struck by this. Why is he considered to be such a powerful intellect by many other powerful intellects? He has had this unique vision of the subject. He was able to connect different things, especially find connections between quantum physics and mathematics.
Almost unparalleled. I don't think anyone comes close, in some sense, in the last, you know, 50 years to him in terms of finding just consistently time after time, breaking ground, new ground, new ground. So he would basically, one way one could describe it is he would take some idea in physics, and then find an interpretation of it in mathematics, and then say distill it, present it in mathematical terms, and tell mathematicians, this should be like that, you know, kind of like 1 plus 2 plus 3 plus 4 is minus 1 over 12.

And mathematics should be like, no way. And then it would plan out, and mathematicians would then like, like a whole industry would be created of groups of mathematicians trying to prove his conjectures and his ideas, and he would always be proven right, you know. So in other words, being able to glean some mathematical truths from physical theories, that's one side. On the other hand, conversely, applying sophisticated mathematics, he's probably the physicist who kind of could learn mathematics the fastest. I don't think I, some younger physicists maybe could come close, but it's still quite, for them a long way to go to get, you know, to be comparable to Whitton, to take some of the most sophisticated mathematics and not learn it to the point where it becomes a practitioner of the subject practically, and then use it to gain some new insights on the physics side. Now, of course, the thing is that the theories that physics, one could say, is in a sort of a crisis, in some sense, because of a current gap between the sophisticated theories, which came from applying sophisticated mathematics
and the actual universe. So we have theories, for instance, we describe 10 dimensional worlds, 10 dimensional space time, coming from string theory, and things like that. But we don't know yet how to apply it to understanding our universe. A lot of progress has been made, but it's kind of a kind of a impasse right now. And at the same time, our most realistic theories, most advanced theories
of the four dimensional universe are in contradiction with each other. The standard model describing the
three known forces of nature, electromagnetic, strong and weak, was great accuracy. And Einstein's relativity, which describes the fourth called gravity. Everybody above a certain age knows that one. So these two theories are in contradiction at the moment. And string theory was one of the the, the promise of string theory was that it would unify those two. And so far, it has not has not happened. So we are kind of at a very interesting place right now. And I think that new ideas, perhaps I need it. And I wouldn't be surprised if written is one of those people who come up with those ideas. Well, he has been one of the, one of the people that added a lot of ideas under the flag of string theory. What do you think about this theory? What do you think is beautiful about it? String theory? Well, first of all, kind of remember, we talked about Pythagoreans and how for Pythagoreans, the whole world was that the symphony where you have this different vibrations of all the humans, every human is a vibration, every, every animal, you know, every being, every tree and every celestial body and so on. So string theory is kind of like that, because in string theory, there is this fundamental object, which is a vibrating string. And all particles are in a sense supposed to be different modulations or vibrations of that string. So that by itself is already interesting that you kind of describe this diversity of various particles and interactions between them using one guiding principle in some sense. But also just the mathematical things that come out of it, the kind of, it looks like impossible to satisfy various constraints. And then there is sort of like a unique way to do it. So that's sort of the, every time that happens when, you know, you have some system over, like over-determined
system. Let's suppose you have to do like five interviews in one day and you wake up in the morning and you're like, that's impossible, because then so many things have to align. For instance, let's suppose you have to go from one place to another. So then you have a commute and then

who knows, maybe there is a traffic jam and stuff like that. And now suppose that it all works seamlessly and there were like a bunch of places where it could have gone hopelessly wrong and it didn't. And then in the evening, you're like, wow, it worked. That's beautiful, right? That's kind of like great luck, you know, we would say. But in science, this happens sometimes, that you have this theory which is not supposed to work because there are so many seemingly contradictory demands on it. And yet there is a sweet spot where they balance each other. So string theory is kind of like this. The unfortunate aspect of it is that it balances itself in 10 dimensions and not in four. So maybe there is another universe somewhere. But see, as a mathematician, for me, all spaces are created equal, 10 dimensional, four dimensional. So mathematicians love string theory because it has given us so much, so much food for thought. But do you think it's a correct or a incorrect theory for understanding this reality? So might be a theory that explains some 10th dimensional reality in some other universe, but is it potentially, what do you think are the odds? Again, financial advice, if you were to bet, what do you think are the odds that it gets us closer to understanding this reality? Well, in the form that it is now, that seems unlikely. But it could well be that based on these ideas with some modifications, with some essential new elements, it could work out. So I would say right now, it doesn't look so good. Like from the point of view that we, from what we know. But maybe somebody will come and introduce like square root of negative one. I mean, they already introduced, but I mean kind of like as a metaphor. Maybe somebody will come and say, what if we do this? It looks crazy. You know, speaking of Niels Bohr, he had this famous quote that he said to somebody, there is no doubt that your theory is crazy. The question is, whether it's crazy enough to describe reality. So that's where we are kind of, you know. Speaking of crazy and crazy enough, let me ask for therapy, for advice, for wisdom in returning to Eric Weinstein and maybe give some guidance to understanding his view on his attempt at theory of everything that he calls geometric unity, that he told me that you may have some inkling of an understanding of. If you were to describe this theory to aliens that visited Earth, how would you do it? Or you could try if it was just me visiting Earth. How would you describe it, your best understanding of it? He shared with me some of it when I was in New York at Columbia, like 11 years ago. We actually spent a lot of time where he explained to me, and I found it beautiful. He has a very original idea at the core of it, where you have this, instead of four-dimensional, instead of 10-dimensional, he has 14-dimensional space. And I thought it was really original, and this exactly goes to the point I made earlier, that we need new ideas. I feel that without some fundamental new idea, we won't be able to get closer to understanding our universe. Now, I have a problem with the whole idea of theory of everything. I don't believe that one exists, nor that we should aim to construct one. And I think it's really not to offend anybody, but it's ultimately a fault of the education system of physicists. Like in mathematics, we're not brought up, we're not educated as mathematicians with the idea that one day we will come up with the theory of everything. Even though, as a joke, I said that Langland's program is a mathematical theory of everything, but I made it kind of tongue-in-cheek. But isn't it a little bit kind of that? It's not really, because first of all, it doesn't cover all fields of mathematics, and it covers specific phenomena. But isn't it spiritually striving towards the same platonic form of the theory of everything? Like connecting. Connecting. But connecting doesn't mean that it covers everything, right? So you could connect two things, and then you have infinitely many other things which are outside of the purview of this connection. That's how it is in mathematics, I feel. And I would venture to say that most mathematicians look at it this way. Like there's no idea that somehow, I think it's actually impossible, because we're not talking about such a thing as like one universe. We're talking about all possible universes of all possible dimensions and so on. It is just not feasible to have a unified, unify everything in one equation. Now physicists, on the other hand, have been brought up, educated for decades with this idea. And to me, and I'm not sure I should say that, but I feel like it's kind of an ultimate ego trip, so that I have come up with the unified. I have found the theory of everything. It's me, and my name will be on it. I think a lot of physicists get educated this way, especially men, take it seriously. And I've seen that happen, and I think it is counterproductive. I think that a lot of people agree that this debate is kind of, I feel like it's kind of settled. I hear it less and less, but I disagree with the whole premise. So you, it's interesting, because both are interesting points you made, which is you don't think a theory of everything exists, and you don't think the pursuit of a theory of everything is good. So I think you spoke to the second thing, which is basically that the pursuit of a theory of everything becomes like a drug to the human ego. That's right. So it is a huge motivating factor. I don't deny that, but I feel that there are better ways to motivate people than like that, than this way. So I would say, for instance, if one, because then it's not a game of winner takes all in some sense. And in fairness, when physicists say theory of everything, grand unified theory, they mean something very specific, which is unifying the standard model in Einstein's relativity theory, which is the theory of gravity. So they don't necessarily, a lot of physicists may say this words, but they don't really mean them. I think it's important to realize that, that in my opinion, that's not productive and it's not feasible anyway. So having said that, there are some theories are better than others, obviously. So for instance, Eric's theory has, as far as I understand, does have a certain way of producing some of the elementary particles that we see, and as well as the force of gravity. So it does have that promise. I feel that, at least from the place where I had seen it about 10 years ago, it still required a lot of work to get to the point of actually saying that it does work because, you know, a lot, there are a lot of elements, it's a huge enterprise to have a theory because you have just to describe the fields, sort of the building blocks of the theory. It's already tremendous undertaking and he's trying to do it for curved spaces in greater generality, which is what makes it so unique and so beautiful. But then there are, on top of that, there are all this issue of quantization of actually describing them as quantum field theory. And the quantum field theory, even as a language, as a framework is currently incomplete, in my opinion, and not only my opinion, it's like everybody agrees on that. It's a collection of tricks, so to speak, it's a collection of tools, it's a toolbox, but it is not a consistent rigorous theory like number theory in mathematics. Physicists have still been able to derive predictions from it, and confirm them with to great accuracy, but the underpinnings, it doesn't have the real rigorous foundation from a mathematical perspective. So in that sense, even if, in that framework, a new theory could lead to a new explanation of some phenomena, it would still be incomplete, in a sense, because it wouldn't be mathematically rigorous, you see what I mean. Because the whole framework is not yet on a firm foundation. So it's not consistent. Why is it that the universe should

have, so that's to your first point, do you think the universe has a beautiful clean
mean? When you show up and meet God, and there's one equation on the board,
and the two of you just chuckle, do you think such equation exists?
Yeah, there are such equations. For instance, let's say I am interested in a particular question,
right? So in the language program, moving away from physics, so let's talk about math. So
in the context of the language program, I have recently developed with my co-authors,
Aitengov and Kashdan, a kind of a new strength, a new flavor of the language program, if you will.
But so far, it's a vision. It's a set of conjectures, which we have proved in some cases,
but not in full generality. So yes, I would like to use your framework for me, the creator,
and ask her, what is the explanation of this? And it may well be that you will answer in a way
that I will just burst out laughing. It's like, how could we not see it? You see? So that I totally
see. But I don't see one equation governing them all. Not one equation to govern them all, but
it does seem that such equations exist, where she will tell you something and you look back and say,
how could I not see it? It seems like the truth at the end of the day is simple,
that we're seeking, especially through mathematics. It seems somehow simple,
the nature of reality, the thing that governs it seems to be simple. I wonder why that is.
And I also wonder if it's not totally incorrect, and we're just craving the simplicity.
And then mixing into the whole conversation about how much the observer that creates simplicity
is part of the answer. It's a whole big giant mess. Or a whole big, beautiful painting or symphony.
You said of Eric Weinstein that I find it remarkable that Eric was able to come up with such
beautiful and original ideas, even though he has been out of academia for so long.
Yes.
Doing wonderful things in other areas such as economics and finance.
I'd like to use that kind of quote as just a question to you about different places where
people of your level can operate. So inside, academia and outside. What is the difference
of doing mathematics inside academia and outside?
Just not even mathematics, but developing beautiful original ideas.
Where's the place that your imagination can flourish most? So the limitations of academia is
there's a community of people that take a set of axioms as gospel. So it's harder to take that leap
into the unknown. But it's also the nice thing about academia is some of the most brilliant
people in the world are there. And it's that community. Both the competition and the collaboration
is there. I wonder if there's something you could say sort of to further about this world
that people might not be familiar with.
But I think you gave a very good description. I'm not sure I can put on it because I don't
have an overarching theory of academia. I definitely have been part of it and I'm grateful
because it gives you a great sense of security, which comes with its own downside too. Because
you kind of get a little disconnected from the real world because you get tenure. So you feel
financial secure. I don't pay you that much, so to speak, relatively speaking. It's comfortable,
but it's not that much. But you can't be fired. So there is something about this,
which I definitely have benefit from it. People are not even aware what it's like to
live outside of where you don't have this type of security. On the other hand,
that also means that we're lacking certain skills that sort of real people in the real world have
developed out of necessity to deal with that sort of insecurity. So it kind of always cuts

both ways. On the one hand, it gives and on the other hand, it takes away. And it's a very interesting setup. And also, on the one hand, we are all supposed to be the true seekers. But in reality, of course, it is a human activity and it is a human community with all kinds of good, bad, and ugly things that happen, a lot of them under the radar screen, so to speak. But maybe there is something to it. There is definitely, there are definitely people who are upholding kind of that old tradition, definitely. And that is inspiring. And I aspire to be one of those, to my best. So whether this is a system that will stay or should stay, I don't know. I really don't know. That's really fascinating. It's fascinating, especially with it, just to introduce the bit of AI poison into the mix, as that changes the nature of education, perhaps as well, with the role of the university is in the next 10, 20, 50, 100 years. I wonder, I wonder, and I wonder that, you know, how do you make sense that Einstein was working after attempting, I believe, to be a university professor?
Or for the patent office.
Yeah, as a patent clerk. But I have to say, to these days, the science has become so much faster. It is really hard to do it being outside. Now, Eric is unique in this way, even though he did go to great undergraduate and graduate schools, but then worked for a while in academia. There are very few examples like that. There's Yutong Zhang, who proved an important conjecture number theory about 10 years ago, and is now, as I understand it, is a professor at UC Santa Barbara. He worked outside of academia and was able to make a tremendous advance on his own.
This case is exceedingly rare, in part because academia is trying to protect its turf and it's kind of, it's creating the sort of prohibitive cost of an outsider. That is true. But there is also something about how much, how much concentration in mathematics. I don't think people who are not,
who are not in the field understand what kind of focus and concentration actually doing, like, mathematics at the top level these days requires. Because we're not talking about something that is more or less good. It is something which is unassailable. It's finding this treasure at the bottom of the ocean without that column, without oxygen. And that's why it's not, people go crazy sometimes. There is a reason for that. Well, let me ask you about that, sort of just to linger on that the amount of concentration required. Cal Newport wrote a book called Deep Work. He's a theoretical computer scientist. He took quite seriously the task of allocating the hours in the day for that kind of deep thinking. And then the mathematicians is theoretical computer scientists
on steroids. So for your own life and what you've observed, let me ask the big question, how to think? How to think deeply? How to find the mental, psychological, pragmatic space to really sit there and think deeply? How do you do it? In the moments you remember where you really deeply thought? Was it an accident? Was it deliberate? No, it's deliberate because, you know, first of all, my first years as a mathematician, I worked every day. Weekends, holidays, doesn't matter. I didn't even question that. So I would feel something's missing if I took a day off. And, you know, so it was just a kind of a sustained effort. The point is that, still the process is nonlinear to go back to what we discussed earlier, that in other words, the way I see it is you just, you are making an effort to bring all the information into focus, what you believe is correct. And you're playing with different ways

of connecting things. But it is a total miracle when suddenly there is inside strikes. It is not something that, in my experience, could be predicted or even anticipated or brought closer. There is a famous story about Einstein that he used to, you know, go, think, think, think, and then go for a walk. And like he would whistle sometimes. So I remember the first time I heard this story, I thought, hmm, how interesting is what a coincidence that this came up to him when he was whistling. But in fact, it's not, this is how it works in some sense that you have to prepare for it. But then the moment, it happens when you stop thinking, actually. So the moment of discovery is the moment when thinking stops. And you kind of almost become that truth that you're seeking. But you could not do it by will in some sense. It's kind of like, you know, how in the Eastern tradition they have this concept of satori, like in Buddhism, in Zen Buddhism, you have this satori, which is enlightenment. And so the various reports of Buddhist monks or Buddhist masters who have had experience satori. But they say, you can't, you can't do it by will. You cannot make it happen. If anything, you have to relax to let it come to you, you know, it's kind of like that. It's kind of like that. So I think that what matters, but you say how to think, the point is that we're talking about such an esoteric area. Like mathematics is really esoteric area. It's a really strange subject where you try to fit everything in this very, very stringent set of rules, to obey those rules.
Isn't it basically the pure, the hardest manifestation of a puzzle that we're all solving in different other disciplines, but this is the hardest puzzle?
But yes or no, because there is just a different,
for instance, there is a different criterion for what constitutes progress. For instance, physics, a lot of arguments they make, they are not rigorous from a mathematical perspective.
It is kind of an intuitive argument. We think it is like this. And this is acceptable in the subject for a good reason. And so there is some play. It's more, it's a more like human activity, day-to-day activity. Like, for instance, if you and I discuss something, you have an idea and I have an idea and we argue about it. And something seems more plausible. Something seems less plausible. And so we may decide to take this point of view or that point of view as a provisional sort of like point of view and go with it. In mathematics, it doesn't work this way.
You either prove it or you don't. And oftentimes, you get to the point where there is this much you need to prove and it just wouldn't come to you. And you just don't see it. And it can go on for months. Super frustrating. But without it, it is nothing, kind of. I would love to hear your opinion to the degree that you know it of the proof of Fermat's last theorem by Andrew Wiles, which seems to have this element perhaps for years. To the degree that you know, perhaps can you explain Fermat's last theorem and what your thoughts are in the process that Andrew
Wiles took that seemed to, at least from my sort of romantic perspective, seem to be very lonely.
Yes. It's a lonely profession. And hopeless. And you put it really nicely because it feels like there's a lot of moments where you feel like you're close. You feel like 90% is done. And there is this one stubborn thing, which just does not compute, you know, doesn't happen. And you're trying to find that push for this last link. And it could take, and nobody knows how long it's going to take. Would it be useful to maybe try to explain from Oz last theorem? Sure. It's easy to do.
I am an optimist. I'm an optimist. I think I always think that everything can be explained, you know, even though I say that not everything can be explained. But in mathematics, you know,

within this particular framework, I think that I always feel optimistic when people ask me to explain something. I always start with the assumption that they will understand. Yes, you know. So let's try. Fermat's last theorem, one of the jewels sort of of mathematics of all time, a beautiful story also behind it. Pierre Fermat, a great French mathematician who lived in the beginning of, mostly worked at the beginning of what 17th century. And he actually has to, he's created a number of important contributions. But the most famous is called Fermat's last theorem or Fermat's great theorem. And the reason why it became so famous is in part because he actually claimed to have proved it himself. And he did it on the margin of a book that he was reading, which was actually an important book by Diophantus about equations with coefficients and whole numbers. And he wrote on the margin literally, this equation, this problem, which I will explain in a moment, I have solved it, I have found a proof, but this margin is too small to contain it. At some point, I was giving a public talk about this and I made it as a joke, I made a tweet in which I wrote that I have proved this theorem, but 280 characters are not enough and it kind of cuts me in mid sentence. So this was 17th century Twitter style proof. But a lot of mathematicians took it seriously because he had great credibility, he did make some major contributions. And the search was on. So for 350 years, about 350 years, it remained unproved with many people trying and failing until in 1994, no, in 1993, Andrew Wiles announced a mathematician from Princeton University announced the proof. And it was very exciting because he was one of the top number theorists in the world. And unfortunately, about a year later, a gap was found. So this is exactly what we were talking about earlier. You have 99% of the proof. This one little thing does not quite connect. And this nullifies the whole thing. Even though, well, you could say there are some interesting ideas, but it's not the same as actually having a proof. So he apparently was really frustrated. And he was really a lot of people thought that it's going to be another 100 years or whatever. And then luckily, he was able to enlist with the help assistance of his former student, also great number theorist Richard Taylor, they were able to do that 1% so to speak. Well, some people might say it may be not one, but 5% or whatever. But it definitely was an important ingredient. But it was not, he had a sort of like a big new set of ideas. And this one thing didn't pan out. They were able to close it with Taylor. And it finally was published and I think was accepted and read in 95 and since it's believed to be correct. Now, what he proved, actually, was not Fermat's theorem itself. But a certain statement, which is called Shimura Taniyama Way Conjecture, named after three mathematicians, two Japanese mathematicians and one French-born mathematician who worked in also the Institute for Advanced Study in Princeton. And it was my colleague at UC Berkeley, Ken Ribbitt, who in the 80s connected the two problems. So this is how it often works in mathematics. You want to prove statement A. Instead, you prove that A is equivalent to B. So after that, if you can prove B, this would automatically imply that A is correct. So this is what happened here. A was Fermat's last theorem, B was Shimura Taniyama Way Conjecture and that's what Andrew Wiles and Richard Taylor really proved. So it requires, to get to Fermat's last theorem, it requires that bridge, which was established by my colleague Ken Ribbitt at UC Berkeley. So now, what is the statement of Fermat's last theorem? Let me start with Pythagoras,

since we already talked about it. Let me start with Pythagoras' theorem, which describes the right triangles. So what is the right triangle? It's a triangle in which one of the angles is 90 degrees, like this. So it has three sides. The longer side is called hypotenuse and then there's two other sides. So if we denote the lengths of hypotenuse by z and the two other sides x and y, then z squared is equal to x squared plus y squared. So that's the equation, or x squared plus y squared equals z squared. And it turns out that this equation has solutions in natural numbers, actually infinitely many solutions in natural numbers. For example, if x equals 3, y equals 4 and z equals 5, then they solve this equation, because 3 squared is 9, 4 squared is 16, 9 plus 16 is 25, and that's 5 squared. So x squared plus y squared equals z squared is solved by x equals 3, y equals 4, z equals 5. And there are many other solutions of that nature.
I would say that natural numbers are whole numbers that are non-negative.
That's right. 1, 2, 3, 4, 5, 6 and so on. Now, what's Fermat's last theorem? Fermat asked what will happen if we replace squares by cubes, for example. So x cube plus y cube equals z cube. Are there any solutions in what do you call natural numbers?
It turns out there are none. What about fourth powers? Again, none.
Oh, it seems like none, right? So that was the statement. So the theorem says that the equation x cube plus y cube equals z cube has no solutions in natural numbers.
Remember, natural means positive whole numbers. So of course, there is a trivial solution 0, 0, 0, so that this works, but you need all of them to be positive.
x to the fourth plus y to the fourth equals z to the fourth also has no solutions.
x to the fifth plus y to the fifth equals z to the fifth, no solutions. So you kind of see the trend. x to the n plus y to the n equals z to the n. If n is greater than 2, has no solutions in natural numbers. That is the statement of Fermat's last theorem.
It's deceptively simple as far as famous theorems are concerned. You don't need to know anything beyond standard arithmetic, addition and multiplication of natural numbers. That's why a lot of people,
both specialists and amateurs, try to prove it because it's so easy to formulate.
So in fact, I think Fermat proved the case of cubes. I think he did actually prove some elsewhere, the case of cubes, but so it remained like fourth. There are infinitely many cases, right? You have to, even if you prove it for cubes and for fourth power and fifth, then still there are six, seven, and so on. There are infinitely many cases in which it has to be proved. And so you see the deceptively simple result took 350 years to prove. And in a sense, it's like mathematicians, you would think mathematics is such a sterile profession. Everybody's so serious, almost like we're all wearing lab coats and take an elevator to every tower. However, look at all this drama. Look at all this drama. It's like we also like drama. We also have narratives. We also have our myths. Here is a guy, a 16th century mathematician
or 17th century mathematician who leaves a note on a margin and motivates others to find the proof. Then how many hearts were broken that they believe that they found the proof. And then later it was realized that the proof was incorrect and so on and brings us to modern day. And one last attempt and reviles who is very serious and respected and esteemed mathematician announces the proof only to be faced with the same reality of his hopes dashed, seemingly dashed. And like there is a

mistake. It doesn't work. And then to be able to recover a year later, how much drama in this one story. It's amazing. But from what you understand, from what you know, what was the process for him
that is similar perhaps to your own life of walking along with the problem for months, not years?
Yes. So he worked, he has given interviews about it afterwards. So we know that he described his process that number one, he did not want to tell anybody because he was afraid that people find out that he's working on it. Because he was such a top level mathematician, people would guess that he has some idea that there is some idea. So you know, if you just know that somebody has an idea, this already gives you a great boost of confidence, right? So he didn't want people to have that information. So he didn't tell anybody that he was working on it. Number one, number two, he worked on it for seven years, if I remember correctly, by himself. And then he thought he had it and he was elated. Obviously, he was very happy. And he announced that at a conference, I think it was in Cambridge University or Oxford University in the UK in 1993, I believe. So you know, this is really interesting because all of us, all mathematicians can relate to this, because I remember very well my first problem, how I solved my first problem. I described it in Love and Math in my book. So I was 18 years old. I was a student in Moscow. And I was just, I just lucked out that I was introduced to this great mathematician. Since I, you know, I was not studying at Moscow University because of anti-Semitism in the Soviet Union. So I was in this technical school, but I was lucky that I had a mathematician who took me under his wing. And Dmitry Fuchs, who actually later came to the US and he's still a professor at UC Davis, actually, not so far from me. So he gave me this problem and it was rather technical, so I will not try to describe it. But I do remember how much effort, you know, that excitement, but also kind of a fear. What if I don't have what it takes? You know, I lost sleep. So this was one consequence of this. For the first time in my life, I had trouble falling asleep. And this actually stayed for a couple of years afterwards. So then it was kind of like a wake-up call that I should be to take care of myself, not work too late and so on. So that was sort of like that experience. And I was lucky that I was able to find a solution, number one, within two months, maybe. And it was very, it was surprising and it was beautiful. Like it, the answer was, was in terms of some something which seemed to be from a different world, from a different area of mathematics.
So it's very happy. But I do remember this moment when suddenly you see that. Just like you, in this case, it was literally, I had to compile these diagrams with what mathematicians call cohomology groups and spectral sequences and manually calculate some numbers and trying to discern some system in it. And suddenly I saw that how they all were governed by this one force, so to speak, one pattern. And that was absolutely, wow. So it's like,
Maybe what was it? So you're sitting there at a desk?
Actually, you know, I lived in a town outside of Moscow. So I used to take, I would take a train to Moscow. So it's what we call in Russia, electric, you know, like this electric train, which was super slow. It took more than two hours to cover that distance. And I think that the crucial insight came when I was in this. And I just, I had to contain myself so I don't start screaming, you know, because there were other passengers in the car. So I was sitting there and staring at this paper. So you know what I remember? That's what came to me. I have something now, which nobody else in the world has. I have a proof of, first of all, it was not just a proof.

Like in the case of Fermat, the statement is already made. That's why it's called conjecture. You know, you make a statement, you don't have a proof yet. Then you try to prove it. In my case, I did not know what the answer would be. There was a type of question where the answer was unknown.
So I had to find the answer and prove it. And the answer was very nice. So nobody knew, as far as I could tell, nobody knew because my teacher told me that he explored all the literature. And this was not known. So this was, suddenly I felt that I was in possession of this. Now, it was a little thing. It was not cure for cancer, you know. It was not a large language model, you know. But it was something undeniably real, meaningful. And it was mine, kind of, you know, like I had it, nobody else. I had not published it. I didn't even tell and even told anybody. And it is a very strange feeling, you know, to have to have that.
Were you worried that this treasure could be stolen?
Not at the time, not at the time. So later on, there were situations where I was exposed to those type of experiences. But at that time, I didn't think of that. I was still this starry-eyed kid, you know, who was just obsessed with mathematics, with this beauty and discovering
those beautiful facts, beautiful results. So I didn't think about, I didn't even think that it could be possible that somebody could steal it or whatever. I just wanted to share it with my teacher as soon as possible, you know. And he understood quickly and he's like, yeah, good job, you know. Is there some something you can give color to the drama? Eric has talked, Eric Weinstein has spoken about some of the challenges, some of the triumphs and challenges of his time at Harvard. So is there some something to that drama of people stealing each other's ideas or not allocating credit enough? Oh, sure. Yes. All of that and creating psychological stressors because of that. Happens all the time, yes, unfortunately. On young minds and so on.
Could have a very bad effect. Is that just the way of life or is this...
I think we can definitely do better. And I think the first step is to kind of admit that we are not 100% secrets of truth, that we are human beings and all the good and bad and ugly qualities can be present and to have some kind of dialogue in my subject, in mathematics. This has not happened yet. There have been some famous cases where people have been accused, which had been resolved or partially resolved or unresolved. And everybody knows it, but there isn't a systematic effort, as far as I can tell, of really trying to create some rules, some ethics rules. This is fair game. This is not fair game. So that as a community, we strive to get better. I think that for most people, it's more like keeping your head in the sand and kind of pretending that it doesn't happen. Or it happens some isolated incidents. Well, my experience is not like that at all. I think it does happen much more often than it should. That's my opinion.
So there's the pool of academia is fascinating. One of the reasons I really love it is you have young minds with fresh ideas. And that same innocence you had when you first on the train have that brilliant breakthrough. And then you throw that in together with senior, exceptional, world-class scientists who have, first of all, are getting older. Second of all, maybe they have partaken in the drug of fame and money and status and recognition. So that starts to a little bit corrupt all of our human minds. And you throw that mix in together.
Yeah. Mostly without rules. And it's beautiful because that's where the ideas of old contend with the new wild-eyed crazy ideas and they clash and there's a tension and there's

a dance to it. But then there's the old human corruption that can take advantage of the young minds. It's unclear what to do with that. I mean, part of that is just the way of life and there's tragedies. And oftentimes when you look at who wins the Nobel Prize, it's also tragic because sometimes so many minds are, the trajectory to the breakthrough idea involves so many different minds, young and old. Yeah. I mean,
you're right. I think it's like everything else. The path is to more self-awareness.
And it's like owning up your own stuff and not blaming other people, not projecting onto other people, but taking responsibility. And that's true for everything. And the problem here, unique problem for mathematics, I would say thesis and chemists are better. They actually have better ethical rules and so on, especially biologists. Because I think in part it's because there is much more money involved because they have to get grants and so on. So for them, the question of priority, who discovered what first is much more serious because there's really some serious money. Mathematics, who cares? You know, like Fermat's last theorem was proved.
Andrew Wilde's become a millionaire? No. I think he got a prize.
He won a prize, but those prizes are not... I think that one was a big prize, but in general, there's not going to be... I think he won the Nobel Prize, eventually, which is about a million dollars. But you know, sometimes I joke about this, that this is the hardest way to win a million dollars. But amongst mathematicians, I think the trouble is that we are so insulated from society because it's such a pure subject. It draws in very specific psychological types. And I can speak about myself. I did not realize it at the time, but later on, I definitely saw...
I mentioned some of it earlier, that for me, mathematics was a refuge from the cruelty of the life I experienced, from discrimination that I experienced when I applied to Moscow University at 16, being failed at the exam and stuff like that, which I describe in my book as well. But that was my way. I was like, I don't trust this world. I don't want to deal with it. I want to hide in this platonic reality of pure forms. This is where I know how to operate. I love this, and I couldn't be bothered in some sense. For a while, up to a point, as I was getting older and more mature, I was becoming more and more interested in other things. But I think that's one of the reasons. And one of the reasons why I wrote Love and Math was precisely to break that cycle. That it's the quiet guy in the corner that goes into math, and not the flamboyant jock or DJ. I wanted to show how beautiful the subject is, to attract this new blood so that different psychological types and more women would join. Because then they would have students who would look at them and whom they will inspire. And then instead of a vicious circle, it would be a virtuous circle. And I have to say, I think it's happening not because of my efforts alone. Obviously, there are many other mathematicians who are around the same time, started to put more effort. Because if the old stereotype of mathematician, you're so enclosed, you're not interested in even exposing the beauty of your subject to other people, you see? And then it becomes this vicious circle. But all the time I meet the students who say, your book is the reason why I chose math as my major. And I am proud, especially when it's women who tell me this. And they are cool. They are DJs at the same time. And they are social. And they have friends. And they go out and so on. You see? So then they carry the torch. Because then they will be more likely to share this beauty with others, to attract more students and so on. So I think this kind of dumbness is broken. So now they have more influx. And once we have people who are more

able to connect at a personal level, that's when we also become more self-aware as a community, I think. And that's when we should have a chance to improve in terms of our ethical rules and stuff like that. So let me return to our friend Eric Weinstein for a question that I would ask anyway. But let's have a non-Russian ask the Russian question. Ask him about the Russian concepts of friendship, science, gender, and love versus the American. So there is a deep romanticism that you have that runs to your book, Love and Math. Is part of that something you've picked up from the Russian culture? What can you speak to that fueled both your fascination with math and your fascination? No, your prioritization of the human experience of love.
Good question. Definitely, there is some influence of the Russian culture, Russian literature, perhaps. But also, there are so many things. How do we develop certain sensibilities? Why do we care about this and not that? Why do I care, for instance, about this romantic ideal, so to speak, of mathematics? That's certainly not something that is automatic. Some people care about it, some people don't. And I'm not saying it is superior or inferior. It's just how my composition, my psychological composition is like that.
And it's an interesting question, what is the cause of it? So I think that we cannot really know, but there are some aspects of it, of course. The life experiences are bringing family. I was surrounded by love by my parents on the one hand, but on the other side, perhaps they were a little overprotective of me. So I was kind of like too much, kind of like taking care of. So then, on the one hand, it developed certain sensitivity, but I was kind of not ready for the challenges of the real world. So then that struggle, and then being lost, and then being able to overcome and to learn. And then if you don't lose, you don't appreciate, maybe. But sometimes when we lose something and then regain it, then we cherish it, we appreciate and then becomes unimportant. Also, various difficulties, you know, the upsetting experiences or one could say traumatic experiences.
Growing up in the Soviet Union, that was not a walk in the park. There were a lot of issues there that I had to go through. And then it doesn't break you, it makes you stronger. But in my case, what happened was that for some of it, it took me 30 years to really come to terms with it and to really understand what happened. It gave me this motivation to strive to become a mathematician, which maybe I wouldn't have otherwise. It charged me, supercharged me. I'm talking about, for instance, I experienced with exam at Moscow University. Can you take me through that experience?
So this is 1984. We spoke about Orwell earlier. And I was applying to Moscow University mathematics department called Mehmet, which is like for people who don't know like the place. It was the only place to study pure mathematics in Moscow, period. But also it's one of the great places on earth. And it's like a huge building, this monolith of a building of Moscow University. Because, as I said, a year earlier, Evgeniy Evgenievich converted me into math, capitalizing on my love for quantum physics. And so I spent a whole year studying with him, and I was already kind of at the level of, you know, in some subjects, the level of like, early graduate studies. So it seemed like it would be a breeze to get into Moscow University. But in fact, little did I know that there was a policy of antisemitism where students like me would be failed by special examiners, mostly during the oral exam with mathematics, but occasionally I would be written tests and stuff. Now, my father is Jewish by blood. It was not religious. His family was not religious. My mom is Russian. And, but I was, since my last name

was my father's name, so it was very easy to read what my nationality was. And so there was a special, can you imagine, there were special people who would screen up applicants who would put aside the files of the undesirables. There would be special examiners who were actually professors at this university, who would be designated as those who would take the exam from those undesirables. It was, it's almost comical when you look back now. And also like questions, why? There was no reason other than just hatred of the other. That's how I see it.
It's just to give a little bit more color. So because you mentioned nationality, it's a little quirk that perhaps gives an insight to the bigger system that the nationality listed on your birth certificate when you're Jewish is Jewish and when you're non-Jewish is listed as Russian.
For me, it was Russian. So first of all, in the inner part, everybody has an internal passport. And there you have first name, patronymic name, last name, date of birth. So these are four. And the fifth colon is nationality, which comes from the nationality of the parents and so on. In my case, it was written Russian because my mom was Russian, but it didn't save me. Because it was my dad's last name. And so anyway, this was the toughest experience that I had up until that point. And there was this two people who came into the room where I was the only undesirable. All other kids were being questioned by other examiners. But they told me that we cannot
question you. We are waiting for special examiners. So I was like, oh, oh, something is food. And so these two guys came. And it's four hours, basically, were asking me questions, which were not in the program and so on. But I was like, yeah, I was 16 years old. I tried to answer it best I can. But it was a setup. It's been documented since then. There are even lists of problems that were given to undesirables in those days. In my year, no Jewish applicants, as far as I know, Jewish by this metric were accepted. So then I had to go to this. There was one school, technical school in Moscow, which was the Institute for Oil and Gas Exploration, which had applied mathematics program.
And that's where me and many of my, many of the kids who were not accepted to Moscow University ended up. And so, but the point is so, and then I was, I was so motivated by this because I went to show those guys, you know, that within five years, less than five years, I got a letter from the president of Harvard University inviting me as a visiting professor to Harvard. I was 21. I was barely 21 because I already did some research in the meantime. That's how motivated I was, you know.
So, but the interesting aspect of it is that for the longest time afterwards, I was telling myself a story that nothing really happened. It wasn't so bad. Okay. So I was failed, but I knew that I was going to succeed. It was 30 years later that I finally got to meet that boy, that 16 year old, that I, that I neglected this time. And I realized that he died, that it was a crushing blow.
The innocence?
Not just innocence, because there was no way, it looked like there was no way I could become a mathematician. Because if I don't, if they don't accept me there, it's over. I didn't know that I could actually find this striving applied math program. And then eventually somebody would take me under his wing and so on, and then could move to the United States. That was not in the realm of possibilities. So in a race, I could, there was nothing to look forward to. It was clear that it's over. I cannot, I cannot do what I love. And so when I finally, when I finally connected to that boy, oh my God, I was totally different experience, all the pain and all the trauma

that came to the surface. And it was a kind of a tsunami. I didn't, I wasn't sure I would survive this. It was so, it was so hard. And what happened was I was invited to, to give a talk about this in New York. It was kind of a spoken word event about science, but like personal experiences related to science. This was almost a year after my book came out. In my book, one of the first chapters is the chapter about this experience. But what I realize now is that I wrote it from the third person perspective. I knew the facts, but I was not emotionally connected to that experience. However, since I wanted to write the book and to connect to my readers, I allowed the boy to write it. So a lot of people were touched by it. And they would, people would say, wow, that chapter, you know, it really got a lot of resonance. It was translated into another language, even before the book was published. I was surprised by this because I didn't know yet. So the adult Edward was not yet in touch, but the book gave the outlet to the child. So, and that kind of started the process. So finally, almost a year later, I'm in New York in this,
this event. And the night before, I'm in my hotel room and I was like, okay, what am I going to talk about tomorrow? And I take a piece of paper just to, you know, my usual like preparation, you know, for things. And then suddenly I have this vision that I will walk up to the microphone tomorrow and I will just start crying. And I was like, by that time, I already had an insight that it's possible to have that kind of a splitting kind of dissociation.
But things were happening quickly. There was someone in my life who explained to me this idea that some things are under the radar of awareness, but they may still influence you. And a lot of that could be connected to some experiences in your childhood. So I was kind of ready for it, from different angles. But I was so surprised because I was like, what is there to remember? I know, I know everything. So then my inner voice says, all right, then you have nothing to worry about. Go tomorrow and you will speak about this. And if you start crying, it's not a problem. I was like, no, I don't want to cry in front of people. I want to find out what it is, what happened. And I sat on my bed, closed my eyes, and it came. So it's hard to describe. So this is what and the sheer energy of it and how much effort it took to suppress it actually for all these years, how much effort it took to build that panzer, I wouldn't say in Russian, that hard core around myself so that and the thing later I realized there were moments when it could come out. And for instance, I developed this fear of public speaking, all kinds of little things that I now feel were connected. So anyway, I saw what happened now through the eyes of that child. I saw how difficult it was, how crushed he was. And it looked completely hopeless. And I felt like, what's the point of living now for me now that I know how cruel this world is, which I didn't realize before, because I prefer to wear this pink, you know, the rose colored glasses. But then something happened. It's so strange. It's like you feel that inside of you, there is this dead child. And it is incredibly sad. I mean, it's like,
I can't even describe it. But suddenly he comes alive. And suddenly it's like,
oh, he's here. And I had a little talk with him. And I said, look, you know, I know,
I know, thank you. I'm so sorry that I neglected you for so long. You know, I didn't know. Thank you for doing this. And it's almost like, you know, I felt like the image came to mind is like a fallen soldier, like you leave a fallen soldier on the battlefield, a wounded soldier. And then you come back to take him with you. And I said, but look, look what we have done. Look at us now. He was not in vain. We are doing okay. And it's kind of almost just like holding, holding, holding that child and that, that sense of who I am, you know, and feeling it.

So the next day I went to the microphone and I let him speak for the first time about his experience in his own voice. It was incredible. People were crying and afterwards came up to me and started sharing stories and so on. Because it is a story, it's a universal story. It's archetypal story. It's the story of rejection and being treated unfairly. We all know it. And I think it's so important to realize that it's, it's possible to revisit those moments. It's possible to reconnect to our little ones. It's possible to bring them back. And we are better for it because this changed my life, this experience. Then there were, then suddenly it's like a floodgates. There were many other things that came. That's when I became interested in the dimensions of imagination and intuition and so on. Because suddenly I realized that I was deprived of those, of that possibility of looking at the world through the eyes of a child because that child was frozen in time. He was not, I was not connected to him. But suddenly he's with me. And he's like, almost like opens his doors and says, look at this, look at this.
So if I could ask you about, there's a difficult idea here. There's a tension.
I've interacted with a few folks in my personal life and in general that have lived through this experience of unfairness and cruelty in the world as young people. And what wisdom do you draw
from the, the, the action you took of not acknowledging that you're a victim to cruelty, but instead just working your ass off, working harder. And then this, the flip side of that is you eventually reconnecting with the cruelty that you experienced. Because if you did that early on, I was not ready for it. It is a defense mechanism. I could be, I could have come, you know, there were kids who commit suicide after this experience. I could have committed suicide because it's too much. And it is well known afterwards, of course, I became aware of all the literature about childhood trauma and so on. And I have been, I've been speaking publicly about it since then too. And so, you know, it is well known issue and well known kind of a universal phenomenon.
I think that interestingly enough, even though, well, now I see a lot of discussion of it, now that my eyes are open, but somehow before I didn't see it. So that, which also shows you how our confirmation bias kind of like how we screen ourselves, how we turn the blind eye to things which do not confirm our views, or for which we are not yet ready. And by the way, nobody should push to do it too soon. I'm glad, I developed certain strengths. I was confident. I was strong to withstand this. And if I weren't, who knows how it could turn out. So it is a very subtle kind of alchemical process, which I don't think there is a recipe, there's a formula. The reason I'm talking about this is just to share this experience, because I think that the only thing we can do in this in some sense is to share with each other, because then we can find, for instance, if somebody shared with me, it would naturally lead me maybe to get closer to that kind of understanding. It's really just personal stories. It's not,
obviously, there is a component where professionals could be involved, professional therapists and so on. In my case, it somehow happened miraculously. Well, I did have support, but not from professional therapists, but from like dear friends. So I did, I did have, you do need, I had somebody at the time who basically held my hand through this experience. Yes, it was invaluable and it could not be done otherwise. So I think it's very common. And here's the thing.
I would not do it in any other way. When I reconnected and I saw all the horrors and so on,

but I also was able to see that my examiners were victims of their own situation, that they became the fell for this bogus theories, or maybe it was more of a issue of career advancement or something. And I also realized they must have suffered as well, because they must have had some kind of consciousness about it, that acting in this way towards basically kids. So it wasn't pretty from their point of view. So I could forgive them. And I could also appreciate what a boost of energy it gave me. If I was accepted and I was just where I was a first year student, I would live in a dorm because I would be probably partying and drinking. And who knows what? Maybe I wouldn't
even become a mathematician. But this focused me like a laser without me even thinking about it. It just happened. I didn't care about anything but doing mathematics and it paid off. It changed my life. So was it good or bad? Paradox. Seems like life is full of those. You said you lost your father four years ago. Yeah. What have you learned about life from your dad? That's another big one. Yeah, because I was very close to him. And it was tough. It was tough. And I was not... I was sort of not ready for it, because up until that point, I lived pretending that death does not exist. When my grandparents died, I was already in the US. So it was very convenient. And I couldn't go back. So I grieved, but it kind of was a bit abstract for me. I didn't see their dead bodies. I didn't bury them and so on. So I waited until the... So the first death in my life was my father, really close loved ones. And I was absolutely devastated. He was such an amazing creature, such an amazing human being. He was the kindest, the smartest, the most funny. It's really funny and just really fun to be with. This is what I miss, obviously. I mean, I would just love to hang out with him. And then suddenly he's not there. So it's tough. But it kind of changed my perspective. You miss him? I miss him tremendously. I miss him tremendously. But in a way, I learned that he never left me in some... I mean, it sounds so... Words are so...
You know, they are... You cannot express in words this, what I'm trying to say.
But... Do you carry him with you? Yeah. But in some sense, I always did. And I saw that, that it's always been... It was really... We were one, in some sense. But there was this experience of two people being together. And that I miss tremendously. But he gave me so much. And, you know, let me tell you one aspect of it, for instance. When he was a kid, his father was sent to Gulag, on Bogus pretenses, right? So he... When he was 16, he applied to university. He wanted
to become a theoretical physicist. By the way, my love for theoretical physics was a large extent, because of that. And he was not accepted, even though he was brilliant, because he was the son of the enemy of the people. And he kind of broke him, this experience, that he didn't care when he was... You know, he went to technical school and he didn't really care. That's my take on it. And then he ended up in this little provincial town. And he thought he would escape from it as soon as possible. And then he met my mother. And they fell in love. And so I am sort of the product of that, you know. Of physics. But then what I learned is that because he was not able to overcome that specific experience, it fell to me to do it. And if I didn't, my son, or my daughter would have. I think that that was one of the things I learned. That was not by chance.
That about the same age, for slightly different reasons. I was subjected to the same kind of unfairness and cruelty. And in some ways, I feel like I did it for him also. I always...
Because he was also always so proud of me. I was so happy. And I was... I had this tremendous gift

twice. I was invited by American Mathematical Society to give this big lectures twice. It was in 2012 and in 2018. And both times they were in Boston. It could be anywhere in the US. Both times was in Boston. Walking distance from my parents' place. So he could be there in my mom as well. And that was such a gift that he was beaming, you know, like seeing me on the stage.
So, you know.
Now that he's no longer here and it's just you.
Well, I still have my mom. I still have my sister.
Yeah, but as a man, there's some aspect that it's...
That it does hit you hard. Are you afraid of your own death? Do you think about your death? Are you afraid of it?
I have a certain conceptual view of life and death today, which is informed by my experiences, in particular, going through my father's death. And that is something which cannot be conceptualized. Like that experience, like you cannot give it to somebody.
One thing I will say is that I felt that what it was, it was actually love, totally exposed, like naked. And you try to throw... It is so acute. So being facing that love is incredibly painful because it's so intense. When a person is alive, we have conversation, we have wars, we have some actions, we have some stuff is going on, and it puts a filter. So we rarely actually feel love in this totally, completely pure, unadulterated state. But when a person dies, it's there. And it's staring at you. And no matter what you do, you cannot turn away. Like I tried to... It's like almost I felt like I want to throw a blanket over it. It burns, like immediately, like boom, gone. It's there. Live through it. And I kept saying to myself, just live through it, live through it. And that's how you also learn what is love, for example. What is it really? What is love? What is life also? Because I was completely... I had no idea. And then you kind of learn that, okay, so maybe it's not quite...
There is more to it. There is more to it. There is more to this experience than what can be put in a concept or in a sentence, in a... Maybe poetry or music can do some justice to it. But if so, then my own life has that component, has that dimension, which is beyond anything I can say about it. And even though I love playing this role, I love it. And it kind of makes me feel different about all kinds of difficulties that arise because it's almost like I want to enjoy it because that's what being human is. It's being terrified. It's being frustrated. It's being self-loathing sometimes. It's not knowing, but also being joyful and just like... Let's just enjoy it. Kind of all of it. That's why you came here for in some sense. You know? It's like not trying to run away from things, but kind of trying to just live through them and appreciate it. So the biggest thing is gratitude in some sense. It's just gratitude. So thank you for letting me play. It's gratitude for every single moment, even if it's dark, even if it's lost. Yes. And that's why I am so... People around me, they all say that it's a total doom and gloom and the world is ending. And I'm like, first of all, that's how you see it, okay? That's not the only point of view. But also, even if it is, that's your challenge. What are you going to do about it? Stop complaining about other people. Do something yourself. How can you make
it a better world? And I think all of that starts with just a gratitude for the moment to be able to play this game. Yeah. How beautiful it is. What we've talked about love, but let me ask, what role does love play in this whole game, in the human condition? It's like the glue,

you know, like for me, it's like... And it's not because people say love is like for human being, like a romantic love, which is a huge component of it, obviously, because it's so, so beautiful to be able to express it in this way. But it could be love for what you do, for your passion for something, you know? Or love for your friends, for instance. Or love, it doesn't have to be. And so, in some sense, that's what it's all about, ultimately, because living without love, it's kind of bland, boring. And so... And I don't think it's possible for science to explain exactly what it is. You can do an evolutionary biology perspective, you can talk about some kind of sociology perspective, psychology perspective, but the experience, the intensity, where you forget, or time, where reminder becomes an illusion, and everything just freezes. Oh my god. And then it's kind of beautiful and painful to hear you say that. When you experience love, the deepest is when you lost it. Yes. But in a sense, you can say that you could not have one without the other. You could not have that deep connection with my father, like really on so, so many levels. If there weren't a moment, that's how I see it. And I'm not trying to say that's how everybody should see. For instance, I respect Ray Kurzweil. I respect, and I feel, and I almost like, I feel good bumps right now. I feel that desire to reconnect, even if it is in the form of a computer program, let's be honest about it. I find it to be very moving. I find it very moving. And I understand because he actually didn't have a chance to spend much time. I think he was 16 or 17 when he was a teenager, when he was dead, died. I was lucky because my father died. I was much older. I've had so many moments with him, but that's not my thing.

I think it is a feature, it's not a bug, and it sounds crazy. I would love, I would give anything to have him here right now. Right now, everything I have, I give it away right now. Where do I sign? Just see him for one hour. I promise you, I will. But I also know that I will, then I'll still lose him or I will die or whatever. So that thing, so why is it so worse to just hold on to, holding on to it? Why? Why are we holding on to this? And I am the first sucker, I'm the first one to hold on. But I'm questioning it now. I'm like, is there another way to approach life where you just, you know, how Buddha, it's like, just let it go. Enjoy and let it go. Enjoy and let it go. Is it possible? Except the paradox of it. Well, ask me in a couple of years, you know. I will report. But I think that, but to my mathematical mind, it sounds like a very interesting idea, to be honest. Because to me, the idea of holding sounds like an impasse. Because no matter, in all my experience, and if you look in history, every time somebody's holding, you know, it's how they said in the matrix, whatever has a beginning has an end. It's like, you cannot go around it. If you have a beginning, you could have an end. So then might as well, just enjoy it and not worry too much about extending it longer. That's how I see it now. But maybe tomorrow will be something else, you know. Yeah, the roller coaster life, the paradox of life. Right. In other words, you're an incredible human being. I've been a fan for a long time. Thank you for writing love and math. Thank you. Thank you for being who you are, being both one of the greatest living mathematicians and still childlike wanderer of the exploring the, how this whole world works, the nature of the universe. And thank you so much for speaking with me today.

This is amazing. It's been a pleasure. Thank you. Thanks for listening to this conversation with Edward Frankel. To support this podcast, please check out our sponsors in the description. And now let me leave you some words from Sofia Kovalevsky, a Russian mathematician.

It is impossible to be a mathematician without being a poet in the soul. Thank you for listening and hope to see you next time.